Report No. TR 250-02
BIO/WEST, Inc.

CHARACTERIZATION OF THE LIFE HISTORY AND ECOLOGY OF THE HUMPBACK CHUB IN THE GRAND CANYON

ANNUAL REPORT - 1990
(CONTRACT NO. 0-CS-40-09110)

Submitted To

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Upper Colorado River Region
Salt Lake City, Utah 84147

Submitted By

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EXECUTIVE SUMMARY

Investigations of the endangered humpback chub were initiated in the mainstem Colorado River of the Grand Canyon on September 1, 1990 by BIO/WEST, Inc, of Logan, Utah. The first month of the project was dedicated to training personnel, assimilating field equipment, defining standard sampling methods, and developing standardized data collection procedures and forms. Five Achilles sportboats were outfitted as research boats including two for electrofishing and three for netting and radiotracking. Equipment for fish sampling, radiotelemetry, water quality, and habitat mapping was also assembled. A **Data Collection Plan** was developed together with a **Fish Sampling Protocol, Fish Handling Protocol,** and **Database Management Protocol.** These documents detail the methodologies to be employed by BIO/WEST in this investigation and were made available to agencies and individuals involved in the Glen Canyon Environmental Studies (GCES).

The study area was defined as 170 miles of river from Kwagunt Rapid (RM 56) to Diamond Creek (RM 226). The region was divided into three sample reaches designated as the Little Colorado River (LCR) Reach, Granite Gorge Reach, and the Havasu Creek Reach. Sampling was conducted monthly in October, November and December with field trips of 10, 20, and 10-days duration, respectively. The 10-day field trips were designed for one team of 6 people to sample the LCR Reach only, while the 20-day trips were designed for two similar teams to sample with approximately equal effort in all three sample reaches.

Six gear types were used to sample humpback chub in 1990, including 1 and 1½" mesh trammel nets, 1½" and 2" gill nets, experimental gill nets, and electrofishing. The 1" and 1½" mesh trammel nets and the 1½" gill nets produced the greatest numbers of chubs (26, 30, and 28, respectively) with approximately equal catch rates of 1.49, 1.57, and 1.45 fish/100 feet/10 hours, respectively. Electrofishing yielded 6 fish with a catch rate of 4.03 fish/10 hours. Gear efficiency will continue to be evaluated in 1991.

Ten species of fish representing five families were captured during the three field trips in 1990. The most abundant species were rainbow trout and carp. A total of 94 humpback chub were captured and released alive; 83 were PIT (passive internal transponder) tagged and 17 were radiotagged (16 with PIT tags). Of the 94 fish captured, 10 had been previously tagged with Floy or Carlin tags by other investigators, 2 were previously PIT tagged by other investigators, and 3 were fish previously PIT tagged during this investigation. Morphometric measurements and meristics were recorded on 46 humpback chub.

BIO/WEST initiated a radiotelemetry study to evaluate its use in the Grand Canyon for assessing habitat use and movement of humpback chub. Preliminary results show that radiotelemetry will be a useful tool in monitoring movement and habitat use of fish in the Grand Canyon and for evaluating the impacts of Glen Canyon Dam operations. Use of radiotelemetry will be further evaluated in 1991. Radiotransmitters were surgically implanted in 17 adult humpback chub which were released in a 5-mile section of the LCR Reach; 10 fish were radiotagged in October and 7 in November. In November, 8 of the 10 October fish were recontacted, and in December 11 of the 17 fish were recontacted for a recontact rate of 80% and 65%, respectively. The position of each fish was determined several times daily to monitor both horizontal and vertical movement (radiosignals are extinguished at about 4 m depth). Radiotagged fish were monitored for 24-hour periods and for 2-hour periods. Movement and habitat use was recorded on standard data sheets and maps, and relative changes in river stage were recorded during these monitoring modes. Eight temporary bench marks were established in the LCR Reach that will eventually be surveyed to permanent U.S. Geological Survey (USGS) bench marks so that all relative stage readings can be tied to absolute stage changes and to the operation of Glen Canyon Dam.

Movement and change in macrohabitat use were noted for radiotagged fish relative to changes in flow, turbidity, and time of day. These variables will continue to be measured and closely monitored during this investigation in order to describe their relationships to fish movement and habitat use. Macrohabitat mapping of areas occupied by humpback chub as well as areas not used by the fish will also continue in order to evaluate the availability of habitat and changes in flow.

A food habits pilot study using nonlethal stomach pumping will be initiated in January 1991 to evaluate the diet of the humpback chub in the mainstem Colorado River. Drift samples will be collected and data gathered from other investigators on benthic invertebrate communities in order to assess the availability of food resources.

Plans were developed for the 1991 investigation including establishing remote radiotelemetry stations to monitor fish movement into the LCR, establishing temporary bench marks to monitor river stage change during radiotelemetry observations, identifying relationships for measuring river turbidity, procuring appropriate maps for macrohabitat mapping, interfacing macrohabitat mapping with development of depth and velocity isopleths to stage relationship being developed by other investigators, and coordinating efforts near tributary inflows and in backwaters with other investigators.

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INTRODUCTION

This Annual Report is submitted to the Bureau of Reclamation (Reclamation) in partial fulfillment of Reclamation Contract No. 0-CS-40-09110, entitled *Characterization of the Life History and Ecology of the Humpback Chub in the Grand Canyon.* This Annual Report summarizes the results of these investigations for the calendar year 1990. It integrates the results of three field trips conducted in October, November, and December, 1990. Trip Reports that detail all activities were submitted following each trip.

This investigation was initiated by BIO/WEST, Inc. (B/W) on September 1, 1990, and is scheduled for completion on October 15, 1994. A review will be conducted of the study at the end of calendar year 1991 by the Aquatic Coordination Team (ACT).

Purpose

The purpose of this investigation is:

> *To conduct in cooperation with the Service and AGF ecological studies to determine the relationship between operations of Glen Canyon Dam and the ecology and life history requirements of the endangered humpback chub population in Grand Canyon.*

This 4-year investigation will focus on the collection and analysis of biological information to test hypotheses about the ecology and life history of the humpback chub in conjunction with the Glen Canyon Environmental Studies (GCES) and conservation measures developed to recover the species. This research is designed to collect information for the Glen Canyon Dam Environmental Impact Statement, and to satisfy portions of two of seven conservation measures arising from a biological opinion on Glen Canyon Dam in 1978. This includes Conservation Measure 5, "Conduct Research to Identify Impacts of Glen Canyon Dam Operations on the Humpback Chub in the Mainstem and Tributaries" and Conservation Measure 7, "Establish a Second Spawning Population of Humpback Chub in the Grand Canyon".

These ecological studies will be conducted to determine the relationship between the operation of Glen Canyon Dam and the endangered humpback chub population in the Grand Canyon. The purpose is to obtain sufficient information on the Grand Canyon population of humpback chub to aid the federal and state agencies in their mandated responsibilities to protect and, where possible, promote the continued existence and recovery of the species.

Objectives

This mainstem investigation will be conducted by B/W concurrently with tributary studies by the U.S. Fish and Wildlife Service (Service), Arizona Department of Game and Fish (AGF), and Arizona State University (ASU) all in cooperation with the Navajo Nation and the Hopi Tribe. These agencies together with the National Park Service (NPS), Bureau of Reclamation (Reclamation) and Glen Canyon Environmental Studies (GCES) comprise the ACT. The objectives of the combined humpback chub investigations are as follows:

Objective 1: **To determine the ecological and limiting factors of all life stages of humpback chub in the mainstem Colorado River, Grand Canyon, and the effects of the of the Glen Canyon Dam operations on the humpback chub.**

- **1A:** **Determine resource availability and resource use (habitat, water quality, food, etc.) of humpback chub in the mainstem Colorado River.**
- **1B:** **Determine the reproductive capacity and success of humpback chub in the mainstem Colorado River.**
- **1C:** **Determine the survivorship of early stages of the humpback chub in the mainstem Colorado River.**
- **1D:** **Determine the distribution, abundance and movement of the humpback chub in the mainstem Colorado River, and effects of dam operations on the movement and distribution of humpback chub.**
- **1E:** **Determine important biotic interactions with other species for all life stages of humpback chub.**

Objective 2: **Determine the life history schedule for the Grand Canyon humpback chub population.**

2A: Develop or modify an existing population model from empirical data collected during the study for use in analyses of reproductive success, recruitment and survivorship.

B/W's field research is partitioned into two efforts. The first focuses on the collection of life history information and habitat use of humpback chub within two intensive mainstem sampling reaches: the Little Colorado River (LCR) Reach and the Havasu Creek Reach. The second effort is a distributional survey and habitat data collection in the intervening reach of the mainstem Colorado River referred to as the Granite Gorge Reach. Data collection will take full advantage of scheduled research flows (predetermined releases from Glen Canyon Dam) to determine the impacts of dam operations on habitat conditions and fish populations in the Grand Canyon. Radiotelemetry is being used in the LCR Reach to determine habitat use and movement of humpback chub. Use of radiotelemetry in areas other than the LCR Reach will be curtailed until the presence of humpback chub is established and the effectiveness of radiotelemetry is fully evaluated.

STUDY AREA

This investigation was conducted in a 170-mile region of the Colorado River in the Grand Canyon from Kwagunt Rapid (RM 56) to Diamond Creek (RM 226) (Figure 1). This region was divided into three reaches including: (1) The Upper Reach from Kwagunt Rapid (RM 56) to Red Canyon (RM 76.5) also known as the LCR Reach, (2) The Middle Reach from Red Canyon (RM 76.5) to Havasu Creek (RM 156) also known as the Granite Gorge Reach, and (3) The Lower Reach from Havasu Creek (RM 156) to Diamond Creek (RM 226) also known as the Havasu Creek Reach. Sampling was concentrated in the confluence area of major tributaries where humpback chub have previously been collected.

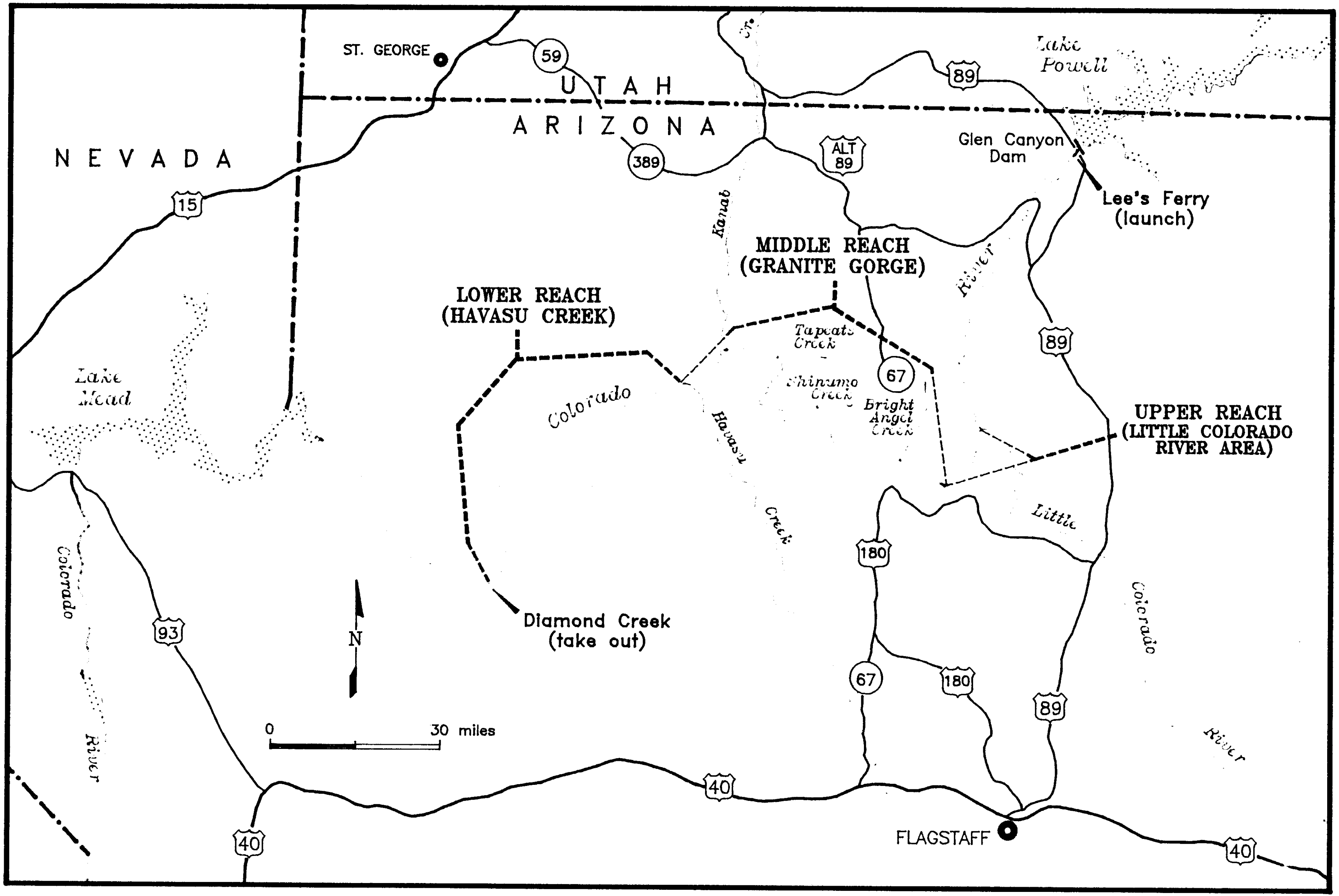

Figure 1. General study area for humpback chub study in the Grand Canyon, showing the three study reaches.

The Upper Reach (LCR Reach)

Fish populations in this 20.5-mile (33 km) reach were sampled intensively with electrofishing gear, gill nets, experimental gill nets, trammel nets, and hoop nets. All available habitats were sampled including runs, eddies, pools, backwaters, side channels, and slackwaters. General habitat parameters were documented to characterize fish capture locations including river mile, surrounding geology, and macrohabitat type. Radiotelemetry was used to document macro and microhabitat used by humpback chub as well as their movements relative to river stage. Riverine habitat was mapped in detail starting in 1991 to characterize occupied, as well as unoccupied habitats. Chemical parameters were measured to further characterize the habitat used by humpback chub and the impacts of Glen Canyon Dam operations on water quality. Since the LCR empties into the upper 5 miles of this reach (RM 61), a concerted effort will be made starting in 1991 to coordinate with AGF and the Service to assess movement of fish between the LCR and mainstem Colorado River.

Previous investigations (Kaeding and Zimmerman 1983, Maddux et al. 1987) have shown that humpback chub seasonally enter the LCR in the spring during spawning activity. It is suspected that many of these fish reside in the mainstem Colorado River within this reach for the remainder of the year. Determining the extent of use of this river reach by humpback chub and the impacts of dam operations on their habitat are the primary objectives of this investigation.

The Middle Reach (Granite Gorge Reach)

This 79.5-mile (129 km) reach contains steep, rocky shoreline habitats typical of areas occupied by humpback chub in the Upper Colorado River Basin (Valdez and Clemmer 1982). The primary purpose for sampling this reach is to refine information on the distribution of the humpback chub in the Grand Canyon, its abundance by age group, habitat use, and habitat availability. The

Granite Gorge Reach was quantitatively sampled with gill and trammel nets, and electrofishing. Radiotelemetry is not planned for this sample reach.

A detailed sampling program was developed for this reach to insure that the reach is sampled as thoroughly as possible. This is important when defining the distribution of humpback chub because their high fidelity to specific river sites (Valdez and Clemmer 1982, Kaeding et al. 1990) dictates the need for thorough sampling.

The Granite Gorge Reach was divided into four longitudinal strata, each characterized by major geomorphologic types that influence fish habitat structure and possibly fish distribution. These longitudinal strata were based on the initial categorization of the geomorphology of the Grand Canyon by Howard and Dolan (1981) which was further differentiated by Schmidt and Graf (1988) into 11 morphologically distinct areas. These geomorphologic classifications are the basis for general fish sample stratification throughout the study area (Table 1). Numerous large rapids in the Granite Gorge Reach may influence specific sample site selection.

Geomorphic strata and sample substrata for the three sample reaches described in this section are shown in Table 2. The four strata in the Granite Gorge Reach were further divided into substrata which were randomly selected for sampling on each 20-day trip. The tributary inflow areas were treated as individual substrata to be sampled at least seasonally since these are areas in which humpback chub were captured in the past. Tributaries inflow areas identified for sampling in the Granite Gorge Reach include: (1) Bright Angel Creek, (2) Shinumu Creek, (3) Tapeats Creek, (4) Kanab Creek, and (5) Havasu Creek.

The Lower Reach (Havasu Creek Reach)

Sampling in this 69-mile (112 km) reach was conducted in the same manner as in the LCR Reach, with the primary objectives of identifying habitats used by humpback chub and other native fish species, and to assess the impacts of dam operations on these important habitats.

Table 1. Characteristics of the geomorphic strata within the Grand Canyon study area.

Reach name and number	Extent of Reach (river miles)	Average ratio of top width to mean depth	Average channel width (feet)	Width character	Channel slope	Average unit of stream power (pounds per foot)	Percentage of bed composed of bedrock and boulders
Lower Marble Canyon (4)	35.9-61.5	19.1	350	Wide	.0010	4.3	36
Furnace Flats (5)	61.5-77.4	26.6	390	Wide	.0021	8.0	30
Upper Granite Gorge (6)	77.4-117.8	7	190	Narrow	.0023	17.6	62
Aisles (7)	117.8-125.5	11	230	Narrow	.0017	10.9	48
Middle Granite Gorge (8)	125.6-139.9	8.2	210	Narrow	.0020	14.2	68
Muav Gorge (9)	140-159.9	7.9	180	Narrow	.0012	9.9	78
Lower Canyon (10)	160-213.8	16.1	310	Wide	.0013	6.2	32
Lower Granite Gorge (11)	213.9-225	8.1	240	Narrow	.0016	10.2	58

[1] Table taken from Schmidt and Graf (1988).

Table 2. Sampling stratification design, Grand Canyon Study.				
Sample Reach	**Geomorphic Strata**	**Sample Substrata**	**River Miles**	**Length (miles)**
#1	Lower Marble Canyon	a. Kwagunt - LCR - RM 56	56.0-61.5	5.5
	Furnace Flats	b. LCR - Chuar Rapid c. Chuar Rapid - Unkar Rapid d. Unkar Rapid - RM 77.4	61.6-65.5 60.6-72.5 72.5-77.4	3.9 6.9 4.9
#2	Upper Granite Gorge	a. Hance Rapid - Cremation Canyon *b. Bright Angel Creek c. Pipe Creek - Crystal Rapid d. Crystal Rapid - Bass Rapid *e. Shinumo Creek f. 110-mile Rapid - RM 117.8	77.0-86.5 86.5-89.0 89.0-96.0 96-107.8 108-109.8 110-117.8	9.5 2.5* 9.0 9.8 1.8* 7.8
	Aisles	g. Aisles	117.8-125.5	7.7
	Middle Granite Gorge	h. RM 125.6 - Dubendorf SSR *i. Tapeats Creek j. 134 Mile Rapid - RM 139.8	125.6-131.7 131.9-134.5 134.5-139.8	6.1 2.6* 5.3
	Muav Gorge	*k. Kanab Creek l. Kanab Rapid - Sinyala Rapid *m. Havasu Creek	139.9-143.6 143.7-153.5 153.6-159.9	3.7* 9.8 6.3*
#3	Lower Canyon	a. RM 160 - RM 169.9 b. RM 169.9 - Lava Falls c. Lava Falls - RM 189 d. RM 189.1 - RM 200 e. RM 200 - 109-Mile Rapid f. 209-Mile Rapid - 217 Mile Rapid	160.0-169.9 169.9-179.4 179.4-189 189.1-200 200-208.9 108.9-217.3	9.9 9.5 9.6 10.9 8.9 8.4
	Lower Granite Gorge	g. 217-Mile Rapid - Diamond Creek	217.8-225.7	7.9

* - Tributary substrata

Radiotelemetry will be used in this reach only if sufficient numbers of adult humpback chub are captured and B/W and the ACT decide jointly to extend the use of this monitoring tool. Sampling in this reach was conducted primarily to collect information on distribution of humpback chub, abundance by age group, habitat use, and changes in habitat availability with changes in flow or discharge.

The Havasu Creek Reach has been identified as an important nursery and rearing area for native fishes (Maddux et al. 1987). Although young-of-year (YOY) and juvenile humpback chub were captured, spawning sites and larvae have not been found to confirm spawning in this reach.

METHODS

The following description of methods applies to the year-round sampling planned for this investigation. A detailed description of methodologies including a **Fish Sampling Protocol, Fish Handling Protocol**, and **Database Management Protocol** are presented in the **DATA COLLECTION PLAN** issued by B/W Janaury 1, 1991. Since field sampling was not initiated until October of 1990, methodologies and schedules were not fully implemented. Winter weather and shortened day lengths hampered sample routines.

Life history data for humpback chub in the mainstem Colorado River will be collected seasonally. This information is critical for determining habitat use at different times of the year, its availability as affected by seasonal operational patterns of the dam, and possible seasonal preference by the species. Field trips will be conducted monthly including six 20-day trips and six 10-day trips per year (Table 3). The trips will alternate between 20-days and 10-days in duration. A total of 39 trips (nineteen 20-day trips and twenty 10-day trips) will be conducted between October 1, 1990 and December 31, 1993. In 1990, 10-day trips were conducted in October and December and a 20-day trip was conducted in November. If it is determined that a particular season or area is more critical and may require more or less sample effort, changes may be made to this sample schedule in a

Table 3. Tentative Trip Schedule; Grand Canyon Study.

Month	1990		1991		1992		1993	
	10-D	20-D	10-D	20-D	10-D	20-D	10-D	20-D
January				X		X		X
February			X		X		X	
March				X		X		X
April			X		X		X	
May				X		X		X
June			X		X		X	
July				X		X		X
August			X		X		X	
September				X		X		X
October	X		X		X		X	
November		X		X		X		X
December	X		X		X		X	
Total	2	1	6	6	6	6	6	6
B/W People per Trip	6	10	6	10	6	10	6	10
Total Person Trips	12	10	36	60	36	60	36	60

bilateral agreement between B/W and the ACT. The following is a brief description of each type of field trip and an outline of daily activities.

Sample Schedule

Twenty Day Trips

The only 20-day trip in 1990 was conducted November 14 to December 3. Of the major purposes of the trip, radiotelemetry was continued with tracking of fish implanted in October and implanting of additional fish. Also, distributional sampling was conducted with electrofishing and gill and trammel nets. Habitat in association with the radiotagged fish and net sets was measured and mapped. General habitat mapping was not conducted because appropriate aerial photographs were not available.Food availability and use by humpback chub was not assessed and is pending studies to evaluate use of nonlethal stomach pumping techniques. Information on biotic interactions was collected by sampling different habitats to evaluate species sympatry.

The following description of the 20-day trips is provided as background information that summarizes the purpose and sample schedule to be used throughout this project. This schedule was not fully implemented during the startup phase in 1990. The purpose of the 20-day trips is to capture humpback chub for implanting radiotags, monitor habitat use and changes with flow, assess limiting factors, and determine important biotic interactions with other fish species. A maximum of ten fish will be implanted with radiotags during each of the 20-day trips for a total of about 60 implants per year. The 20-day trips involve two independent field teams (Figure 2) each with a designated Project Leader with extensive river fisheries experience. Team 1 has 6 B/W and 1 ACT biologists and will work in the LCR Reach while Team 2 with 4 B/W and 1 ACT biologists works concurrently in the Granite Gorge Reach.

TWENTY-DAY TRIPS

Personnel: 10 B/W + 2 ACT
Boats: 2 Electrofishing + 3 Netting/Tracking Sportboats; 2 37-foot S-rigs + 2 23-foot Snouts.

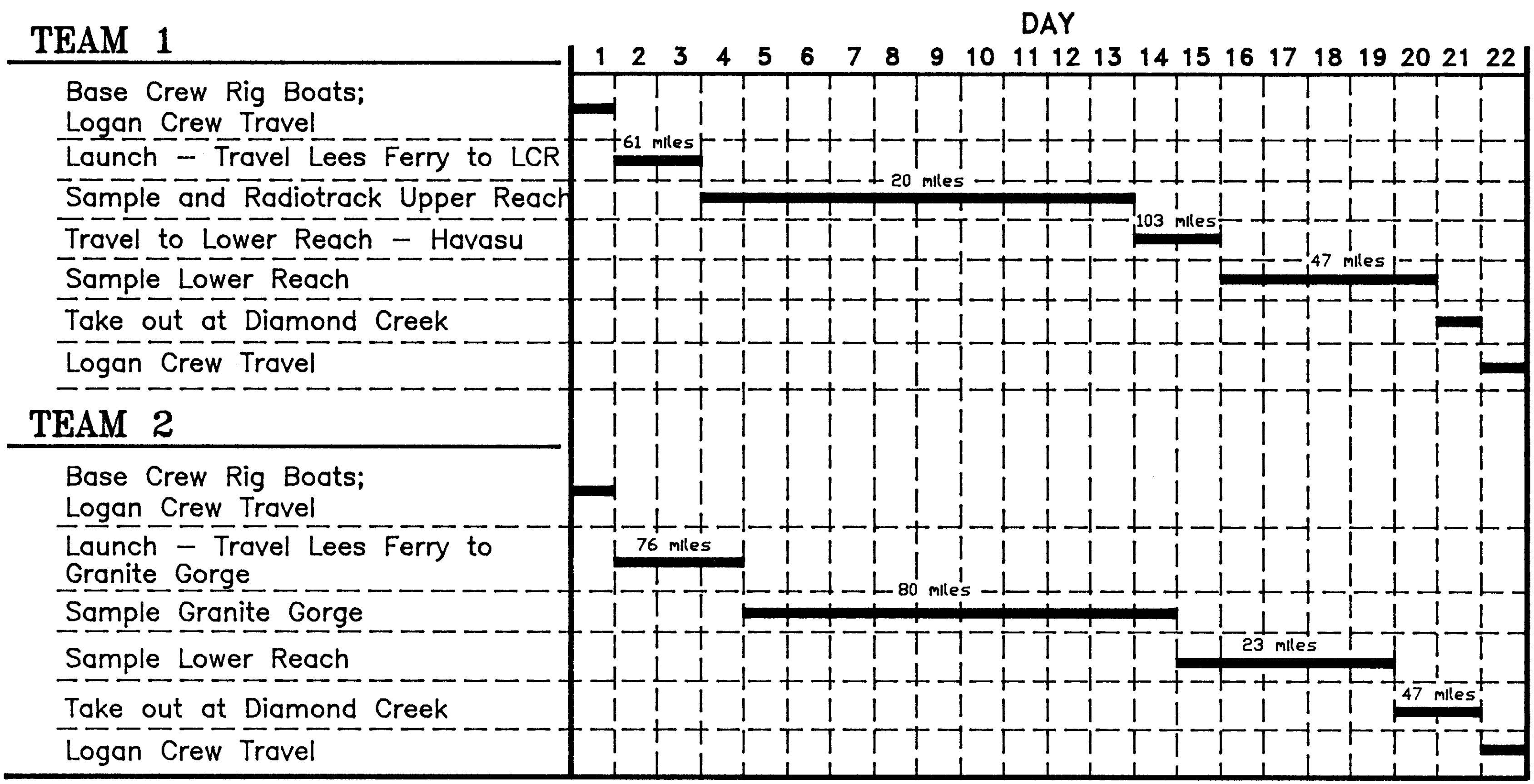

Figure 2. BIO/WEST's travel and sample schedule for 20-day trips.

Team 1 will use three 16-foot research sportboats (one for electrofishing and two for netting and radiotracking), and Team 2 will use two 16-foot research sportboats (one electrofishing and one netting/tracking). Of the five research boats, B/W will provide one electrofishing and three netting/tracking boats and Reclamation will provide one electrofishing boat. The research boats will be rolled and loaded on the support S-rigs (33 or 37-footer) whenever possible to minimize human risk, reduce loss of research equipment, and to minimize researcher visibility in the Grand Canyon to recreationists. One S-rig (33 or 37-footer) and one J-rig (23-foot snout boat) will accompany each of the two teams. These support rafts are provided by OARS, a commercial river concessionaire from Flagstaff, Arizona, contracted by GCES to provide logistical support for research efforts in the Grand Canyon.

The sampling schedule is designed to allocate an approximately equal amount of field sample time to each of the three sample reaches. In November 1990, Team 1 sampled the LCR Reach for about 10 days while Team 2 sampled the Granite Gorge Reach. The two teams jointly sampled the Havasu Creek Reach during the last 5 days of the trip. Thus, each of the three reaches was sampled for approximately 10 days. This sampling schedule will be implemented on all 20-day trips in 1991. The following chart outlines the sample schedule for each team on the 20-day trips. A more complete schedule that includes travel is presented graphically in Figure 2.

TEAM 1		TEAM 2	
ACTIVITY	DAYS	ACTIVITY	DAYS
Travel to LCR Reach	2	Travel to Granite Reach	3
Sample LCR Reach	10	Sample Granite Reach	10
Travel to Havasu Reach	2	Sample Havasu Reach	5
Sample Havasu Reach	5	Travel to takeout	2
Travel to takeout	1		

Ten Day Trips

Two 10-day trips were conducted in 1990, one each in October and December. These trips were designed to concentrate sample effort in the LCR Reach with the purpose of recontacting previously radiotagged fish and monitoring their movement and habitat use. Since the October trip was the first of this investigation, the primary objective of this trip was to implant ten adult humpback chub with radiotags. Fish were also implanted in November. The December trip was conducted primarily to monitor fish that were radiotagged in October and November. Throughout these trips, and until June 1991, research activities are designed to monitor fish activity and habitat changes in response to scheduled research flows from Glen Canyon Dam.

The following is a description of the sample schedule for the 10-day trips. Sampling rountines were only partially implemented during startup in 1991, with an emphasis on radiotelemetry. The 10-day trips will involve one field team with 6 B/W and 1 ACT biologists (Figure 3). Following sampling, 3 or 4 B/W people will hike out at Phantom Ranch while the remaining 2 or 3 proceed to the Diamond Creek takeout with the OARS crew to disassemble gear and return to Flagstaff.

The team will use three 16-foot research sportboats (one electrofishing and two netting/tracking) and one 33-foot support boat. The three research boats were motored through the canyon in October and in December, two of the research boats were rolled and loaded on one 33-foot S-rig and one 23-foot J-rig which remained with the team during the entire trip. The third research boat was motored through the canyon. The following outlines the sample schedule for the team on the 10-day trips.

ACTIVITY	DAYS
Travel to LCR Reach	2
Sample LCR Reach	6
Travel to takeout	4

TEN–DAY TRIPS

Personnel: 6 B/W + 2 ACT.
Boats: 1 Electrofishing + 2 Netting/Tracking Sportboats; 1 37–foot S–rig + 1 23–foot Snout.

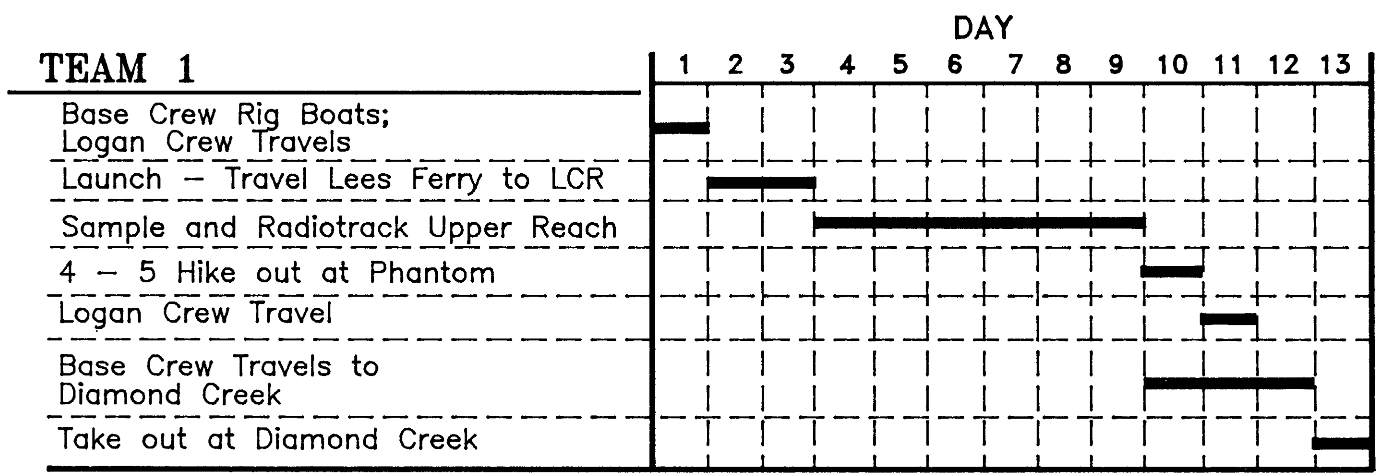

Figure 3. BIO/WEST's travel and sample schedule for 10-day trips.

Sampling Fish

Electrofishing

Two electrofishing boats were available for sampling starting in October 1990. The electrofishing apparatus were assembled by B/W and Reclamation biologists so that the two systems are similar with interchangeable components. The two systems were tested in the area of Lee's Ferry with the assistance of Mr. Norm Sharber of Coffelt Manufacturing. Electrofishing was not used as extensively as anticipated because of the time required to check and clean gill and trammmel nets. Increased efficiency with setting and cleaning nets and additional personnel should allow for greater use of electrofishing as a tool in this investigation.

Electrofishing will be used in this investigation to sample fish of all sizes in shallow shoreline habitats of all three sample reaches. Electrofishing will be used as a primary sample method to characterize fish assemblages for comparisons between sample areas and for the same area over time. Electrofishing will also be used to capture humpback chub for implanting radiotags. Where possible, results of electrofishing efforts will be separated by major geomorphological shoreline type (e.g. sheer wall, talus, sand beach) by conducting discrete runs within each habitat type. The number of fish captured by species in a discrete effort will be recorded and related to time for calculation of catch-per-unit effort (CPU) expressed as number of fish per 10 hours of effort.

Electrofishing will be conducted from SU-16 Achilles Sportboats with the capability to up-run and navigate small and medium-sized rapids for increased access to sample areas. Each is designed to meet Occupational Safety and Health Administration (OSHA) safety requirements with specialized equipment such as safety switches, insulated railing, separate line-channeling for circuits, rubber gloves, boots, lights, etc. Each system is powered by a 5000-watt Yamaha industrial grade generator Model YG-500-D. Power from the generator is routed through a Mark XX Complex Pulse System (CPS) developed by Coffelt Manufacturing where the current is transformed from a 220 volt AC to pulsed DC current. The pulsed DC current is then supplied to the water through to one anode (+) mounted on a boom projecting from the front of the boat and a cathode (-) suspended from the stern. Stainless steel spheres manufactured by Coffelt Manufacturing are used as electrodes. Output settings on the CPS are expected to range from 15 to 20 amperes and 300 to 350 volts as recommended by Coffelt Manufacturing for electrofishing in the Colorado River below Glen Canyon Dam (Personal Communication with Norm Scharber, October 9, 1990). The anode and cathode are interchanged every 45 to 60 minutes of electrofishing to allow for cleaning of the cathode surface by reversing the electroplating process.

All fish captured during electrofishing are processed immediately upon completion of a run within a specific habitat type. Each fish is visually examined for evidence of injury associated with electrofishing. Any fish showing signs of injury (e.g. burn marks, spinal deformity, failure to recover) is noted. Nontarget fish are released immediately after processing generally within 0.1 to 0.2 mile of the point of capture. Humpback chub are transported to a central processing station near camp but released at their capture location.

Greater electrofishing effort is planned on the 20-day trips in 1991 than was conducted in November. More efficient scheduling of field crews will allow regular monitoring of gill and trammel nets and free personnel to conduct electrofishing.

Nets

Gill Nets. Gill nets were used extensively in 1990 and will continue to be used as a primary sample gear to characterize fish assemblages of shallow to deep shoreline habitats. This gear type will be used to compare fish distribution and abundance by area and for the same area over time, as well as to categorize general fish habitat use. A variety of mesh sizes will be used to capture all adult and most juvenile fish. The number of fish captured by species from a net set will be recorded for calculation of catch-per-unit effort expressed as the number of fish per 100 feet of net per 10 hours.

Three types of gill nets will be used including 1) standard 1½" gill net; 2) standard 1" gill net; and 3) experimental gill nets consisting of four mesh sizes, 2",1½",1",½", graduated from large to small mesh at 25 foot intervals. All nets are 100 feet in length and 6 feet deep, and constructed of double knotted #139 nylon multifilament twine. Float and lead line consist of ½" diameter braided poly foamcore float line and 5/16" braided leadcore leadline, respectively. White mooring boat bumpers will be used as net floats and markers for high visibility. These will be labeled to alert other boaters of their purpose. Polypropylene mesh bags filled with rocks serve as net weights. Nets will be checked at least every 2 hours to minimize stress and reduce mortality of entangled fish. Nets clogged with *Cladophora glomerata* or debris will be replaced.

Trammel Nets. Trammel nets were also used extensively in 1990 and will be used with gill nets to characterize fish assemblages and to document changes in fish distribution and abundance over time and area. Trammel nets will also be used as an active gear by floating nets through areas of fish concentrations, such as during spawning time. This technique may be used occasionally in areas of low current and smooth sand bottom.

Trammel nets consist of three panels of netting, two outer walls of large mesh and one inner panel of a small mesh. The outer walls on all trammel nets will consist of #139 multifilament twine netting with a 12" mesh. The inner panel will consist of one of two different mesh sizes, either 1" or 1½"; these mesh sizes have been found most effective for capturing humpback chub with a minimum of damage. All inner panels will be constructed of double knotted #139 nylon multifilament twine.

Seines. Seines were not used extensively in 1990. Their use will increase in 1991 to sample various shoreline habitats including runs, riffles, pools and backwaters. This gear will be used primarily to characterize small fish assemblages in shallow habitats. For each seine haul, the length and width of the habitat sampled will be measured as well as maximum water depth. The length and width of the haul will also be measured and three water depths recorded, one at the deepest point of the haul, and one each midway from the deepest point to the nearest shore. These measurements will allow researchers to express the number of fish captured in terms of surface area (number of fish per 10 square meters). Each backwater seined will be checked for longitudinal thermal gradients prior to seining. If significant temperature differences occur, extreme care will be taken to not subject the fish to thermal shock during seining, holding, and release.

Fish captured in a seine will be kept in the water while all endangered and native fishes are removed and placed in live wells (bail buckets). The seine is then beached and a second intensive search is made. After all endangered and native fish have been removed the remainder of the fish are placed in a live well. Fish captured with seines will be identified in the field and released live at capture locations. Specimens that cannot be identified afield will be preserved in 3 to 5% formalin and placed in an appropriately-labeled sample jar. Incidental mortalities will also be preserved. All preserved fish will be returned to the BIO/WEST laboratories for further identification and processing. Specimens will be transferred annually to the Service or AGF as required by scientific collecting permits.

Three sizes of seines will be used for this study including 30'x6'x1/4", 15'x6'x1/4" and 10'x4'x1/8" (length x height x mesh size). The top or float line is constructed of 5/16-inch braided polypropylene with hard foam floats placed at 18-inch intervals. The bottom line consists of braided polypropylene line with lead sinkers placed at 6-inch intervals.

Fish Traps

Minnow Traps. Unbaited minnow traps will be used in 1991 to sample small fish in a variety of habitats including backwaters, small embayments, rocky shorelines, and pools. Minnow traps used for the study will be standard Gee Minnow Traps, 17½ inches long, 9 inches in diameter, constructed of galvanized wire and steel. Openings are located on both ends of the trap.

Traps will be placed on the bottom or suspended in the water column depending on conditions. Each trap will be tethered to a secure anchor point and flagged for easy location. Traps will be checked at least every 8 hours to minimize stress and mortality. Fish captured in traps will be transferred to live wells for immediate processing.

Hoop Nets and Frame Nets. Hoop nets were used in 1990 and will be used in 1991 in various low velocity habitats such as slow runs, pools, backwaters shoreline indentations and side channels. Two sizes of hoop nets will be used including 2'x 10'x ½" and 4'x 16'x 1" (diameter x length x mesh size). Two wings made of 1" #15 nylon will be attached to the opening of the hoop nets. Each wing is 25 feet in length.

Hoop nets will be set by anchoring the rear of the net to the substrate with a length of rebar or fence post and the mouth oriented in a downstream direction to capture upstream moving fish. Nets will be checked at least every 8 hours to minimize stress or mortality.

Frame nets (similar to hoop nets except for differences in the shape of the net frame and configuration of the lead or wing) will be set and used in the same manner as hoop nets. Fish captured in the hoop and frame nets will be placed in live wells for processing and released immediately near the point of capture.

Angling

Angling has been used as an effective method for capturing humpback chub in the upper Colorado River Basin, including Black Rocks and Westwater Canyon (Valdez et al. 1982) and Yampa Canyon (Tyus and Karp 1989). The most effective baits included native grasshoppers, cheese balls, salmon eggs, artificial flies, and Mormon crickets. No live baits (e.g. Mormon crickets or grasshoppers) will be used on this project to avoid introduction of exotic insect species into the Grand Canyon ecosystem.

Angling will be used to capture humpback chub in deep pools that are otherwise inaccessible to other sample gears. Angling for this species is also successful along vertical shoreline cliffs. This gear may also prove effective for capturing fish determining feeding periodicity through stomach analysis. Fish captured by angling will be processed immediately and released. Angling effort will be recorded as time spent with line in the water.

Handling Fish

A **Fish Handling Protocol** was developed by BIO/WEST that details the methods to be used in this investigation for handling fish. The elements of this protocol were implemented during the three 1990 field trips. Every effort was made to minimize stress to the fish. Gill and trammel nets were checked at least every 2 hours and all fish captured were placed immediately in live wells with fresh water. Electrofishing was monitored closely and all fish were checked for evidence of injury.

Non-target species (flannelmouth suckers, bluehead suckers, rainbow trout, brown trout, brook trout, carp, channel catfish, speckled dace, and Plains killifish) were measured, weighed and released immediately at the point of capture--either immediately after each electrofishing run or each net check. Each humpback chub was placed in a live well and returned to a central processing station located at camp. Each chub was measured as total (TL), standard (SL), and forked length (FL); weighed in grams; PIT tagged if over 175 mm TL; and photographed on a centimeter grid board with still and video cameras. One of every ten chubs over 200 mm TL was measured for meristics including depth of nuchal hump, head length, distance between the insertion of the pelvic and pectoral fins, maximum body depth, maximum caudal peduncle depth, minimum caudal peduncle depth, length of anal fin base, length of dorsal fin base, and dorsal and anal ray counts. Humpback chub large enough to radiotag (550 gm for 11-gm tags and 450 gm for 9-gm tags) were isolated in a live well and taken to the surgery tent (See Surgical Implant Section of Radiotelemetry).

Radiotelemetry

Fish Transport and Holding

A total of 17 adult humpback chub were equipped with radiotransmitters in 1990. Each fish was handled with particular care and attention to minimize stress. This included holding the fish in a separate live well for transportation to a surgery station and constant monitoring to insure that no signs of stress were exhibited.

The surgery station included a surgical tent and a fish processing area that were set up and maintained for the duration of each trip. As the fish were brought to the station in live wells, they were measured, weighed and PIT tagged in the fish processing area. Then, each humpback chub was photographed on a white grid board, and fish designated for radio-implant were transferred to the surgical tent. The fish were kept in live wells with fresh river water at all times.

Radiotag Implanting

Telemetry Check. All radiotags were checked for frequency and pulse when received from the factory. Frequency and pulse rate were rechecked prior to implantation and immediately following release to insure that the transmitter was functional and that frequency and pulse rate were accurately recorded.

Surgical Procedures. A thorough review of the literature on surgical procedures for radioimplant was conducted for this investigation. The surgical procedures used are modified from Bidgood (1980) and Tyus (1982, 1988) and were outlined in Yard et al. (1990). Only individuals thoroughly trained in the appropriate surgical procedures were allowed to implant radiotags.

All surgeries were performed inside a tent to minimize exposure to blowing sand and reduce the risk of infection. All instruments were cold sterilized in 90% isopropyl alcohol and allowed to air dry on a disposable sterile cloth. Gortex CV3 suture on a PH 26 curved needle was used instead of 3-0 Ethilon because Gortex is easier to handle, has greater tensile strength, and integrates into tissue to promote faster healing and less tissue damage.

The radiotags were cold sterilized to reduce the possibility of peritoneal infection. Other researchers (Tyus 1982, 1988) have coated the transmitters with beeswax to provide an inert surface and reduce peritonitis and tag expulsion. The manufacturers of the radiotags contend that the epoxy resin that encases the electronic components of the transmitter is less irritating and can be more effectively sterilized than beeswax (Personal communication with Michael Shuster, ATS; Lee Carstonsen, Smith-Root, Inc.). Beeswax also adds undesired weight and bulk to the transmitter.

Care was taken to select fish that were healthy and showed no signs of stress. Fish were selected for radio-implant on the basis of body weight and robust appearance. The criterion was established that the air weight of the tag did not exceed 2% of the body weight of the fish. Thus 11-gm tags were implanted in fish that weighed more than 550 gm, and 9-gm tags were implanted in fish weighing more than 450 gm.

Fish were anesthetized with tricaine methanosulfate (TMS or MS-222) mixed in a live well. Surgery was performed on a special cradle with the fish out of water. Respiration and general condition of the fish were monitored throughout the surgery. Fresh water and anesthesia were alternately administered to the gill area of the fish from large bail buckets via 3/4-inch diameter 5-foot long surgical hoses. Flow through the hoses was controlled with pinch clamps.

Surgery began immediately and was usually completed in less than 6 minutes. An incision approximately 3 cm long was made along the abdominal midline of the fish ending about 2 cm anterior to the pelvic girdle. Other investigators conducting radiotelemetry studies of humpback chub (Valdez and Clemmer 1982, Valdez and Nilson 1982, Kaeding et al. 1990), bonytail (Chart and Lucas 1990), Colorado squawfish and razorback sucker (Tyus 1982, 1988; Valdez and Masslich 1989) placed the abdominal incision laterally along the base of the rib bones. The midline incision technique was used in this study because it was determined that the linea alba (midline) is a facial plane that is stronger than muscle fibers and heals quicker. It also has little vascularity and few nerves so there is less damage from the incision. This promotes rapid resumption of normal behavior.

The distal tip of the transmitter antenna was grasped with a pair of curved mosquito forceps used to guide the antenna into the incision and posterior along the inner abdominal wall to an area about 1 cm posterior to the pelvic girdle at which point a small 5 mm nick was made for exit of the antenna. The transmitter was then guided into the abdomen to rest on the pelvic girdle while pulling the antenna to full length. The larger abdominal incision was then closed with 3 or 4 sutures and the smaller nick was closed with one anterior and one posterior suture. This procedure for locating the external antenna is also a deviation from standard techniques which employ a large hollow needle instead of the mosquito forceps. The above described procedure is favored because there is less risk of internal damage from the smooth tipped forceps.

Tracking

Aerial Radiotracking. Aerial tracking was conducted once in 1990 prior to the December trip. Aerial tracking will be conducted prior to each field trip to provide field crews with approximate locations of radiotagged fish. Aerial tracking will be conducted from a helicopter, flying at an altitude of 500 to 1000 feet and speeds of up to 80 mph.

Two types of radio receivers will be used for aerial tracking, one Model 2000 ATS programmable receiver (programmed with specific radio frequencies) and one Smith-Root SR-40 simultaneous scanning receiver (programmed with frequency bands). Each will be attached to one of two Larsen-Kulrod omni-directional whip antennae mounted to the skids of the helicopter. The antenna on the pilot's side will be connected to the Model 2000 ATS receiver and the antenna on the passenger's side will be connected to the SR-40 receiver. Output signals from both receivers will be routed through a switch box to two sets of headphones, one for the tracker and one for the pilot.

This enables the tracker to quickly identify signal frequency and pulse rate by switching between the scanning and programmed receivers.

All active transmitter frequencies will be programmed into the Model 2000 ATS programmable receiver prior to each aerial tracking effort. A list of all frequencies and pulse rates for active transmitters and the last known location of the transmitter will be available to the tracker. Surveillance flights will proceed in a downstream direction for the entire length of the study area. Since the SR-40 has the capability of simultaneously scanning all frequencies, the chance of missing signals is minimized and tracking speeds is not as restricted as with cycling search receivers.

The resolution of fish locations is expected to be within 0.1 to 0.2 miles. When frequency is confirmed, fish location is plotted on a map for latter transfer to a field crew. Aerial tracking continues until all of the transmitters have been located or a reasonable search has been conducted.

Ground Radiotracking. Radiotracking is conducted from the research and logistic boats during all downstream travel, beginning at Lee's Ferry and continuing to the take out point for each trip. Radio receivers are stowed in water-proof boxes in whitewater sections, but remained accessible so that tracking efforts can continue once rapids have been negotiated. Tracking my be conducted from more than one boat at a time to simultaneously monitor both sides of the channel, although this tracking mode may not be necessary since signal strength is usually sufficient to be received by a boat at midchannel.

Radiotracking is done with either the Smith-Root SR-40 scanner or the ATS Model 2000 programmable receiver using Larsen-Kulrod omni-directional whip antennas mounted on large metallic base plates such as cargo boxes.

Multiple surveillance runs are made daily through the reach of river occupied by radiotagged fish. The purpose for these surveillances is to determine diel use of near-surface habitats and regions deeper than about 4 m.

Individual radiotagged fish will be monitored for either 2 hours or 24 hours to characterize local movement and habitat use. Fish chosen for monitoring in 1990 were not randomly selected because each was not consistently contacted in water shallower than about 4 m. Thus, fish were monitored when their radio signal was audible. When a fish was contacted, an attempt was made to determine its general location from the boat using an ATS Model 2000 receiver and a directional loop antenna. When the general location was established, the tracking boat was taken to the shore nearest the fish taking care to not disturb the fish. An ATS Model 2000 programmable receiver and directional loop antenna were used from shore to triangulate the position of the fish in the channel.

Fish monitored for 2 hours are first observed for 30 minutes to determine if their position is static or dynamic. If the fish is stationary, its location is triangulated and marked. The fish is then monitored for an additional 1½ hours to determine habitat use. Triangulation sightings are marked for all locations where a fish remains stationary for 30 minutes or more during the 1½ hour monitoring period.

If the fish is moving, its movements are monitored for an undetermined amount of time to ascertain its behavior and or movement patterns in relation to various factors including: 1) stage changes; 2) local macrohabitats and/or; 3) other radiotagged fish in the area. If the fish becomes stationary, it is monitored as described above for a stationary fish.

Fish monitored for 24 hours in 1990 were carefully observed for habitat use and movements particularly during changes in flow stage. In future trips, each movement by a fish and each area occupied for longer than 30 minutes will be mapped on a mylar overlay over a 1:2400 scale photograph of the area. River stage, recorded on temporary bench marks, is recorded for each observation for the fish. Generally, fish monitored for 24 hours are checked every 1 to 2 hours or more frequently if river stage changes rapidly.

A detailed hand drawn map or a detailed map using mylar overlay of an aerial photo (depending on photo availability) will be prepared for each fish that is monitored. Distance and direction of all movements are recorded on the map and in the telemetry log relative to time and stage of the river.

At the conclusion of monitoring, habitat measurements are taken at all locations where the fish was stationary for at least 30 minutes. Habitat measurements taken at each point include depth, velocity, substrate, temperature, overhead cover, and lateral structure. Procedures for measuring each of these microhabitat parameters are presented in the Microhabitat Measurements Section below.

Remote Telemetry. Two remote telemetry stations will be located near the mouth of the LCR early in 1991 to monitor radiotagged fish moving into that tributary from both upstream and downstream directions. The upstream station will be located on river left just above the LCR and the downstream station will be located about 1 km downstream from the LCR on river right. These sites were selected because of their proximity to the LCR confluence and because of the relatively shallow channel that will insure receiving radio signals from moving fish.

Programmable ATS Model 2100 receivers will be used at each station with compatible analog ATS dataloggers. These receivers will be housed in small boxes to protect instrumentation from the elements and to minimize vandalism. The housing units will be painted a neutral color and discretely located to reduce visibility from the river. Yagi antennas will be used to detect a radiotagged fish passing through the area. The dataloggers will record individual frequencies and time of day on a continuous scanning mode.

Information will be downloaded from the dataloggers on every trip (approximately 2-3 week intervals) onto 5 1/4 inch diskettes using a laptop computer. Backup copies of diskettes will be made before the memory on the dataloggers is erased.

Habitat Assessment

Microhabitat Measurements

Microhabitat will be measured in conjunction with radiotelemetry monitoring to characterize habitat used by adult humpback chub. Depth, velocity, substrate, overhead cover, and lateral structure will be recorded at each location occupied by a radiotagged fish for 30 minutes or more.

Measurements of physical habitat will be taken either from a boat or by wading to the point located by triangulation. Depth will be measured to the nearest tenth of a meter using either a telescoping meter rod or a wading rod. In areas where the total depth exceeds the length of the metered rod, depth will be taken using a fathometer. Water velocity will be measured with a Swoffer current meter to the nearest tenth of a meter per second at the same location as the depth measurement. Velocity of the water column will be measured at 3 cm off the river bottom, and at two-tenths, six-tenths and eight-tenths of the water depth. In extremely deep water, an effort will be made to collect as many of the column velocities as possible. Selection of the depths of water velocity measurements will be made using a top setting wading rod to facilitate correct depth selections. Measurements taken in eddies or reverse river currents greater than 90 degrees from the main directional flow of the river will be recorded as negative velocities.

Substrate will be categorized as silt, sand, gravel, cobble, boulder or bedrock by visual observation, probing with depth rod, or physical examination. Substrate categories are described in Table 4. The two most common substrates will be recorded and classified as either dominant or subdominant. The substrate which accounts for the greatest surface area will be considered dominant. The second most commonly occurring substrate will be considered subdominant.

Table 4. Substrate categories and descriptions.

Substrate	Description
Silt	fine material <.062 mm in diameter
Sand	coarse fines .062 - 2 mm in diameter
Gravel	particles 2 to 75 mm in diameter
Cobble	particles 75 to 300 mm in diameter
Boulder	particles >300 mm in diameter
Bedrock	substrate a solid rock shelf

Cover at the fish location will be characterized in terms of lateral, overhead and instream cover based on observations at the microhabitat sampling location. Overhead cover is characterized as overhanging banks such as rock ledges or streamside vegetation. Lateral cover includes vertical rock walls and boulders. Instream covers types include boulder, log or debris jam, sand shoal, or rock jetty.

Flow/Stage Monitoring

Eight temporary bench marks (TBM) were established in 1990 in a 5-mile area of the LCR reach. Variation in river stage will be monitored with temporary staff gages surveyed to these TBMs. These TBMs will be established at strategic locations in order to relate fish movement and habitat use to river stage. Each TBM will be surveyed into one of the 50 permanent USGS bench marks at a later date so that relative stage changes can be related to absolute changes and thus to specific flow releases from the dam. Temporary staff gages will be employed during field trips for radiotelemetry monitoring and habitat mapping and will be placed close to radiotagged fish or within an area to be mapped for simultaneous readings.

Habitat Mapping

Areas commonly occupied by humpback chub will be intensively mapped to document changes in macrohabitat and use of those habitats by the fish under different river flows. Areas selected for mapping will be determined from repeated captures of fish and routine use by radiotagged fish. Areas not occupied by humpback chub will also be mapped to contrast with habitats that are used.

Base maps will be constructed from aerial photographs using overlays of acetate sheets to hand-sketch habitat features visible to the investigator at different river stages. A different overlay will be developed for a different flow stage so that the change in area by habitat type can be assessed.

As part of the mapping effort cross-sectional profiles of the river section being mapped will be constructed using boat mounted fathometers. Bathymetric contours will be determined at known flow stages. The number of cross-sectional profiles used to characterize the a river section will depend on the variability of the channel morphology. A minimum of three cross-sectional profiles will be used in each mapping section. More refined bathymetric profiles of depth and velocity are being developed by L. Stevens which will be used in combination with our habitat mapping efforts to characterize fish habitat in three-dimension.

The mapping effort will be supplemented with photography. Photographs will be taken from established photo points for each area mapped using the same film size and lenses with similar focal lengths to facilitate comparisons over time. The following is a list of macrohabitats as these are defined for the purposes of mapping:

Habitat Type	Definition
Backwater	A sheltered body of water bound by land on three sides and with one opening (BA) to the river. Backwaters have no measurable velocity and are created by a drop in water level which eliminates flow through a secondary channel or a sand depression.

Backwaters are also created at high water by flooding mouths of washes or other low-lying areas.

Eddy — A portion of the river, usually deeper than the adjacent channel, with a distinct (ED) whirlpool or counter-current. An eddy is usually created by obstructions in the channel or projections of land or rock from the shore. Lateral and upstream boundaries are denoted by an eddy line, shear zone, or a land mass; downstream boundary is denoted by the release of flow from the region of counter-current.

Pool — A stretch of the river that is deep and quiet. A pool generally has lower surface (PO) velocity than the adjacent channel, and is often characterized by small surface boils and upwellings; the boundaries of a pool are marked by dramatic increases in velocity and depth.

Run — A stretch of relatively deep, fast laminar flow. A run has no large surface boils (RU) or upwellings, and it may be deep or shallow. Slow runs and fast runs are segregated by average water column velocities of less than or greater than 2.0 fps.

Slackwater — A habitat similar to a slow run, but with very low velocity created by instream (SW) structure such as a sand shoal, emergent island, or an eddy. Unlike pools, slackwaters have no surface boils or upwellings, and they may not be deeper than adjacent areas; unlike runs, slackwaters have much lower velocity.

Riffle — A shallow area with distintly broken surface.

Rapid — A relatively deep area with large standing waves.

Run/Rapid — A relatively deep area with small standing waves.

Water Quality

Collection of water quality data was initiated in 1990 with an assessment of important water quality parameters and sample locations. This program will be further developed in 1991 with the assistance of Mr. Bill Vernieu, water quality specialists for GCES. This program will also be coordinated in 1991 with a study to monitor ambient and in situ light intensity in the Grand Canyon.

Basic water quality data will be collected to supplement physical habitat measurements. Parameters to be recorded include dissolved oxygen, temperature, pH, conductivity, salinity, redox potential, and turbidity. All parameters except turbidity will be collected with a Hydrolab Surveyor water quality monitor. Water quality data will be collected at various locations within the study at various times of the day and night. A water quality log will be maintained for each trip.

RESULTS

Sample Effort

Fish were sampled in 1990 during trips 1 and 2 (October and November), primarily with electrofishing gear and nets (Table 5). Fish were not sampled during trip 3 (December) to allow more time for radiotracking. Reach 1 (LCR) was sampled during trips 1 and 2, while Reaches 2 and 3 were sampled only during trip 2, which is consistent with sample schedules for 10 and 20-day trips.

Six different gear types were used in 1990 (Table 5). The effort with each gear type was not necessarily equal between trips or reaches because the crews were in the process of establishing sample routines, testing relative gear efficiencies, and determining most effective gear types and set locations.

Table 5. Sampling effort hours by trip for each of the three sampling reaches, Grand Canyon Studies, 1990[1].

Gear[2]	Reach 1			Reach 2			Reach 3			Total
	Trip 1	Trip 2	Total	Trip 1	Trip 2	Total	Trip 1	Trip 2	Total	
EL	5.00	3.20	8.20	-	4.00	4.00	-	2.70	2.70	14.9
TL	62.86	38.95	101.81	-	64.12	64.12	-	89.61	89.61	255.54
TK	30.70	54.57	85.27	-	58.92	58.92	-	90.09	90.09	234.28
GM	40.43	10.36	50.79	-	71.38	71.38	-	51.82	51.82	173.99
GP	53.93	66.74	120.67	-	28.85	28.85	-	48.69	48.69	198.21
GX	15.68	19.72	35.40	-	7.18	7.18	-	14.85	14.85	57.43
HL	-	-	-	-	87.31	87.31	-	43.10	43.10	130.41
HS	-	-	-	-	61.73	61.73	-	-	-	61.73

1- Fish were not sampled during Trip 3.
2- See Table 6 for definitions.

Gear Effectiveness

The majority of humpback chubs (56) were captured with trammel nets (Table 6). The 1½" (TL) and 1" (TK) mesh nets captured approximately equal numbers of chubs (30 and 26, respectively). The three types of gill nets jointly yielded 32 chubs. The 1½"-mesh captured 28 while the 2" mesh and the experimental gill nets captured 3 and 1 chub, respectively. Only six chubs were captured by electrofishing. No YOY chubs were collected by netting but several chubs from 96 to 143 mm TL were captured by electrofishing.

Gross catch-per-effort (CPE) for the six gear types (Table 6) indicate approximately equal catch rates for the 1½" (TL, 1.57 fish/100'/10 hours) and 1" (TK, 1.49) mesh trammel nets as well as the 1½" (GP, 1.45) gill nets. Catch rates for the 2" (GM, 0.17) and experimental gill nets (GX, 0.17) were substantially lower. However, electrofishing produced the highest catch rate for humpback chub in 1990 with over 4 fish/10 hours. A conclusive evaluation of gear types can not be made because of small sample sizes, particularly for electrofishing. However, the 1990 data indicate that 1" and 1½" mesh trammel nets and 1½" gill nets are effective for capturing adult chubs in the mainstem Colorado River in Grand Canyon. Electrofishing may provide an even more effective means for capturing chubs, particularly the younger fish that are not caught in nets. A complete evaluation of gear types will not be available until the end of the 1991 sample year.

Trammel and gill nets were set for maximum periods of 2 hours to minimize stress to the fish. All humpback chub captured with these gears were in good condition with a mimimal of abrasions and no mortalities. Accumulations of *Cladophora glomerata* necessitated replacing nets after 2 to 6 hours of fishing to minimize avoidance by the fish. The nets were spread on sand beaches, allowed to dry, and the debris brushed away. Dry and cleaning nets required a substantial amount of time by personnel, but the number of humpback chub captured with no mortalities supported the effort.

Table 6. **Numbers of humpback chub captured by gear type, Grand Canyon Studies, 1990.**

GEAR TYPE	Number of Chubs	Gross CPE (no/hrs)[1]
Electrofishing		
EL - 220-V DC	6	4.03
Trammel Nets		
TL - 75' x 6' x 1½" x 12" Trammel net	30	1.57
TK - 75' x 6' x 1" x 12" Trammel net	26	1.49
Gill Nets		
GM - 100' x 6' x 2" Gill net	3	0.17
GP - 100' x 6' x 1½" Gill net	28	1.45
GX - Experimental Gill net	1	0.17
Hoop Nets		
HL - Large hoop net (4' diam.)	0	-
HS - Small hoop net (2' diam.)	0	-
TOTAL	**94**	**94**

1- Gross catch-per-effort (CPE computed from total hours; trammel nets adjusted to 100 feet.)

Species Composition and Distribution

Summaries of all fish species captured in 1990 by study reach and trip are presented in Tables 7 and 8. Reach 1 was dominated by rainbow trout (64.78%) with humpback chubs comprising nearly 20% of all fish captured. Rainbow trout also dominated the catch in Reach 2 (62.46%), and carp were second in abundance with 16.61%. Humpback chubs comprised only a small fraction of fish collected in Reach 2 (0.33%). Reach 3 was dominated by common carp (48.48%) with rainbow trout second in abundance (31.82%), while humpback chubs increased to 4.55% of all fish captured. Flannelmouth suckers and channel catfish comprised 6.06 and 7.58% of the catch, respectively in Reach 3.

Summary of Humpback Chub Captured

A total of 94 humpback chub were captured in 1990 (Table 9). Of these, 83 were PIT tagged and 17 were radiotagged. All fish were photographed with still and video cameras, and meristics were measured on 46 fish.

All but three of these fish were collected in Reach 1. One chub was collected in Reach 2 near Shinumo Creek (river mile 108.3) and two were collected in Reach 3 near Pumpkin Spring (river mile 213.6).

A total of 83 humpback chubs were PIT tagged by B/W during 1990. Forty-two chubs were PIT tagged in October and 41 in November. All radiotagged fish were also PIT tagged, except for one that was inadvertently omitted. Three B/W PIT tagged chubs were recaptured during November 1990. These chubs were recaptured only days after their original tagging and one fish had moved about 1 mile.

Twelve chubs were recaptured from previous AGF tagging efforts (Tables 10 and 11). In October 2 Carlin and 3 Floy-tagged chubs were recaptured. Five Carlin and 2 AGF PIT tagged chubs were recaptured in November. All 12 of these recaptured chubs were originally tagged in the Little

Table 7. Fish species composition by trip for each of the three sample reaches, Grand Canyon Studies, 1990[1].

Species[2]	Reach 1			Reach 2			Reach 3			Total
	Trip 1	Trip 2	Total	Trip 1	Trip 2	Total	Trip 1	Trip 2	Total	
HB	45	45	90	-	1	1	-	3	3	94
FM	11	12	23	-	24	24	-	4	4	51
FV	0	1	1	-	0	0	-	0	0	1
BH	0	1	1	-	5	5	-	0	0	5
RB	122	176	298	-	188	188	-	21	21	507
BR	8	11	19	-	28	28	-	1	1	48
BK	0	1	1	-	2	2	-	0	0	3
CC	1	0	1	-	2	2	-	5	5	8
CP	13	12	25	-	50	50	-	32	32	107
SD	0	0	0	-	1	1	-	0	0	1
PK	0	1	1	-	0	0	-	0	0	1
SUM	200	260	460	0	301	301	0	66	66	826
Electrofishing (hrs)	5.00	3.20	8.20	-	4.00	4.00	-	.70	2.70	14.90
Netting (hrs)	203.60	190.34	393.94	-	379.49	379.49	-	338.16	338.16	1111.59

1- Fish were not sampled during Trip 3.
2- Species: HB = humpback chub
FM = flannelmouth sucker
FV = flannelmouth sucker variant
BH = bluehead sucker
RB = rainbow trout
BR = brown trout
BK = brook trout
CC = channel catfish
CP = carp
SD = speckled dace
PK = plains killifish

Table 8. Percentage of species by trip for each of the three sample reaches, Grand Canyon Studies, 1990[1].										
Species	Reach 1			Reach 2			Reach 3			Total
	Trip 1	Trip 2	Total	Trip 1	Trip 2	Total	Trip 1	Trip 2	Total	
HB	22.50	17.31	19.57	-	0.33	0.33	-	4.55	4.55	11.38
FM	5.50	4.62	5.00	-	7.97	7.97	-	6.06	6.06	6.17
FV	0	0.38	0.22	-	0	0	-	0	0	0.12
BH	0	0.38	0.22	-	1.66	1.66	-	0	0	0.61
RB	61.00	67.69	64.78	-	62.46	62.46	-	31.82	31.82	61.38
BR	4.00	4.23	4.13	-	9.30	9.30	-	1.52	1.52	5.81
BK	0	0.38	0.22	-	0.66	0.66	-	0	0	0.36
CC	0.50	0	0.22	-	0.66	0.66	-	7.58	7.58	0.97
CP	6.50	4.62	5.43	-	16.61	16.61	-	48.48	48.48	12.95
SD	0	0	0	-	0.33	0.33	-	0	0	0.12
PK	0	0.38	0.22	-	0	0	-	0	0	0.12

[1]- Fish were not sampled during Trip 3.

Table 9. Summary of humpback chub captured in 1990, Grand Canyon Studies.

Total Caught	Pit Tagged	Radio Tagged	Recaptured	Meristics
94	83	17	15	46

Table 10. Summary of Humpback Chub handled during 1990.

#	DATE	GEAR TYPE	PIT TAG	RECAP	OLD TAG	TL (mm)	WT (gm)	RM (capture)	RM (release)
1	10/17/90	GP	7F7F3E3454	Y	0315176[4]	355	430	60.4	60.4
2	10/17/90	GP	7F7F3F3626[6]	Y	068[3]	432	780	60.4	60.4
3	10/17/90	GP	7F7F3F441C	N	-	353	370	60.4	60.4
4	10/17/90	GP	7F7F3E3370	N	-	329	515	60.4	60.4
5	10/17/90	GP	7F7F3E2D2D[6]	N	-	439	865	60.4	60.4
6	10/17/90	TL	7F7F3F5050[6]	N	-	428	840	60.2	60.4
7	10/17/90	TL	7F7F3E2253[6]	N	-	382	535	60.2	60.4
8	10/17/90	TL	7F7F3E4067	N	-	365	530	60.2	60.4
9	10/18/90	GP	7F7F3F4054[6]	Y	305673[5]	415	720	60.4	60.5
10	10/18/90	GP	7F7F3E2A49	N	-	332	405	60.4	61.2
11	10/18/90	GP	7F7F3F452E	N	-	382	510	60.4	61.2
12	10/18/90	GP	7F7F3F396A	N	-	374	690	60.4	61.2
13	10/18/90	TL	7F7F3F5044[6]	N	-	388	580	60.6	60.5
14	10/18/90	TL	7F7F450272	N	-	451	790	60.2	61.2
15	10/18/90	TL	7F7F3F4577	N	-	367	495	60.2	61.2
16	10/18/90	TL	7F7F3C4554	N	-	413	800	60.2	61.2
17	10/19/90	GM	7F7F451157	N	-	392	540	65.4	65.5
18	10/19/90	GM	- ESCAPED -			-	-	65.4	

Table 10 (continued)

#	DATE	GEAR TYPE	PIT TAG	RECAP	OLD TAG	TL (mm)	WT (gm)	RM (capture)	RM (release)
19	10/19/90	GP	- ESCAPED -			-	-	64.6	-
20	10/19/90	TK	7F7F3F4F47	N	-	240	160	65.2	65.5
21	10/19/90	TK	7F7F3C3F16	N	-	260	160	65.2	65.5
22	10/19/90	TK	7F7F3E271F	N	-	340	400	65.2	65.5
23	10/19/90	TK	7F7F3F4F30	N	-	287	215	65.2	65.5
24	10/19/90	TK	7F7F3C2925	N	-	223	94	65.2	65.5
25	10/19/90	TL	7F7F3F4747	N	-	344	350	64.6	65.5
26	10/19/90	TL	7F7F3E2B52	N	-	332	370	64.6	65.5
27	10/19/90	TL	7F7F3F4E11[6]	N	-	376	465	64.6	65.5
28	10/19/90	TL	7F7F3C2419	Y	360[2]	355	440	64.6	65.5
29	10/20/90	GM	7F7F3C2B55	N	-	405	745	65.4	65.5
30	10/20/90	GP	7F7F3E3E51	N	-	325	320	64.6	65.5
31	10/20/90	TK	7F7F3C2B56	N	-	342	455	65.0	65.5
32	10/20/90	TK	7F7F3E2F3A[6]	Y	0314021[4]	367	500	65.0	65.5
33	10/20/90	TL	7F7F3E2E29	N	-	404	550	64.6	65.5
34	10/20/90	TL	7F7F3C311C[6]	N	-	395	525	64.6	65.5
35	10/20/90	TL	7F7F456B2C[6]	N	-	390	605	64.6	65.5
36	10/20/90	TL	7F7F3F5043	N	-	334	405	64.6	65.5
37	10/21/90	EL	7F7F3C3A12	N	-	372	410	65.0	65.5

Table 10 (continued)

#	DATE	GEAR TYPE	PIT TAG	RECAP	OLD TAG	TL (mm)	WT (gm)	RM (capture)	RM (release)
38	10/21/90	EL	-	N	-	100	8	65.0	65.0
39	10/21/90	TK	7F7F3F4C73	N	-	297	312	65.0	65.5
40	10/21/90	TK	7F7F3F480D	N	-	398	638	65.0	65.5
41	10/21/90	TK	7F7F3F4E06	N	-	341	140[B]	65.0	65.5
42	10/21/90	TK	7F7F3E3804	N	-	290	270	65.0	65.5
43	10/21/90	TK	7F7F3C3956	N	-	221	116	65.0	65.5
44	10/21/90	TL	7F7F3C3000	N	-	203	58	65.0	65.5
45	10/21/90	TL	7F7F3F4B71	N	-	334	345	65.0	65.5
46	901116	GP	7F7F3F470E	N	-	343	385	60.1	61.2
47	901116	GP	7F7F3C303B[6]	Y	578[1]	396	665	60.1	60.2
48	901116	GP	7F7F3F4B54	N	-	377	314	60.3	61.2
49	901116	GP	7F7F3F4C44	N	-	282	270	60.3	61.2
50	901116	GP	7F7F3F3B6A	N	-	331	340	60.3	61.2
51	901116	GP	7F7F3E2F26	N	-	370	565	60.1	61.2
52	901116	GP	7F7F3E2F28	N	-	352	410	60.1	61.2
53	901116	GP	7F7F3F4630	N	-	349	250	60.3	61.2
54	901116	GP	7F7F3E2720	N	-	355	465	60.3	61.2
55	901116	TL	7F7F3E2D41	Y	603[2]	294	270	60.4	61.2
56	901116	TL	7F7F3C6C11	Y	-	335	292	60.4	61.2

Table 10 (continued)

#	DATE	GEAR TYPE	PIT TAG	RECAP	OLD TAG	TL (mm)	WT (gm)	RM (capture)	RM (release)
57	901116	TL	7F7F456643	Y	-	330	336	60.4	61.2
58	901116	TL	7F7F3E4105	N	-	361	392	60.4	61.2
59	901116	TL	7F7F3E4044	N	-	334	392	60.4	61.2
60	901116	TL	7F7F3C4452[6]	N	-	404	672	60.4	60.4
61	901117	GP	7F7F3F4E77[6]	N	-	407	675	61.0	61.0
62	901117	GP	7F7F451C79	Y	936[3]	311	270	61.0	61.2
63	901117	GP	7F7F3C4538	N	-	373	475	61.0	61.2
64	901117	GP	7F7F3E2E73	N	-	390	520	61.0	61.2
65	901117	TK	7F7F3E3310	N	-	367	420	61.0	61.0
66	901117	TK	7F7F3E232E	N	-	360	289	61.1	61.1
67	901118	GP	7F7F3F4E02	N	-	382	502	61.0	61.2
68	901118	TK	7F7F3E2B6B	Y	316[2]	393	585	61.1	61.2
69	901118	TK	7F7F3C277A	N	-	294	252	61.1	61.2
70	901118	TL	7F7F3E3C5C[6]	N	-	422	798	61.1	61.1
71	901119	EL	-	N	-	143	25	62.0	62.0
72	901119	GP	NO PITTAG[6]	N	-	407	825	62.0	62.0
73	901119	GP	7F7F3C2F4B	N	-	359	330	62.0	62.0
74	901119	TK	7F7F3E2739	N	-	365	450	62.0	62.0
75	901119	TK	7F7F3E4105	Y	-	-	-	61.5	61.5

Table 10 (continued)

#	DATE	GEAR TYPE	PIT TAG	RECAP	OLD TAG	TL (mm)	WT (gm)	RM (capture)	RM (release)
76	901119	TK	7F7F43407F	N	-	405	645	61.5	61.5
77	901121	GX	7F7F3C4477	N	-	380	519	64.2	64.2
78	901121	TK	7F7F3F4802	Y	113[2]	368	604	64.3	65.5
79	901121	TK	7F7F3E2D14	N	-	390	537	64.3	65.5
80	901121	TK	7F7F450E4C	N	-	363	488	64.3	65.5
81	901121	TK	7F7F3C2919[6]	N	-	394	635	64.1	64.1
82	901122	EL	-	N	-	96	7	64.8	65.5
83	901122	EL	7F7F3C4455	N	-	263	221	64.8	65.5
84	901122	EL	7F7F3E317C	N	-	303	257	64.8	64.8
85	901122	TK	7F7F3E290D	N	-	335	274	64.4	65.5
86	901122	TL	7F7F3C3F17	N	-	338	367	64.6	65.5
87	901123	GP	7F7F45574B	N	-	363	562	64.9	64.9
88	901123	TK	7F7F451644	N	-	225	125	108.3	108.4
89	901123	TL	7F7F3C264C	N	-	352	520	64.4	65.5
90	901123	TL	7F7F3C4162[6]	N	-	402	732	64.4	64.4
91	901124	TL	7F7F3C4477	Y	-	380	497	65.4	65.5
92	901130	TL	7F7F3E3212	N	-	318	280	213.6	213.6
93	901201	TK	7F7F3E3212	Y	-	318	257	212.5	212.5
94	901201	TL	7F7F3F4B6C	N	-	330	280	213.6	212.8

Table 10 (continued)

[1] Small red carlin tag
[2] Small yellow carlin tag
[3] Small orange carlin tag
[4] Yellow floy tag - AGFD
[5] Orange floy tag - AGFD
[6] Fish implanted with radio transmitter

Table 11. Movements of humpback chub evaluated by recapture location, Grand Canyon Studies, 1990.

Tag Type	Tag Number	Original Capture Date	Original Capture Location	Recapture Date	Recapture Location
Yellow floy tag - AGFD	0315176	5/1/86	Mouth of LCR, RM 61.5	10/17/90	60.4
Small orange carlin tag	068	5/11/89	300 meters up LCR	10/17/90	60.4
Orange floy tag - AGFD	305673	5/25/85	LCR RM 61.5	10/18/90	60.4
Small yellow carlin tag	360	-	No data	10/19/90	64.6
Yellow floy tag - AGFD	0314021	6/3/86	Mouth of LCR RM 61.5	10/20/90	65.0
Small red carlin tag	578	5/3/87	Mouth of LCR 61.5	11/16/90	60.1
Small yellow carlin tag	603	5/23/88	LCR SD Hoop	11/16/90	60.4
Pit	7F7F3C6C11	4/23/90	LCR SS D Hoop	11/16/90	60.4
Pit	7F7F456643	5/2/90	Mouth of LCR 61.5	11/16/90	60.4
Small orange carlin tag	936	5/25/90	LCR notch	11/17/90	61.0
Small yellow carlin tag	316	5/21/88	LCR confluence 61.5	11/18/90	61.1
Small yellow carlin tag	113	5/18/88	LCR NR RR Tie	11/21/90	64.3
Pit	7F7F3E4105	11/16/90	61.2	11/19/90	61.5
Pit	7F7F3C4477	11/21/90	64.2	11/24/90	65.4
Pit	7F7F3E3212	11/30/90	212.5	12/01/90	213.6

Colorado River or at its confluence with the mainstem Colorado. Several chubs exhibited movements up to 5 miles from their original point of capture.

Radiotelemetry

Number radiotagged

A total of 17 humpback chub were implanted with radio transmitters in 1990 (Tables 12 and Table 13). Two sizes of transmitters with external antennas were used: 11 gms (Model 2 w/ 10-35 battery) and 9 gms (Model 2 w/ 10-18 battery). Thirteen and four transmitters of the respective sizes were used. An analysis of weight-frequency for the 94 humpback chub captured in 1990 shows that 19 fish (20% of total) weighed 450 to 549 gms, while 24 fish (26%) weighed 550 gms or more (Figure 4). Thus, in 1990, 46% of the humpback chub captured were large enough to receive a radiotag.

It is possible to use transmitters as small as 9 and 11gm because the external antenna allows for greater signal strength. Internal-antenna transmitters of comparable strength would have to weigh 16 gms. In order to maintain the criterion that tag weight cannot exceed 2% of fish weight, only fish weighing 800 gms or more could be implanted. In 1990, only 4 fish (4%) satisfied this criterion, and all were females. Thus, continued use of external-antenna transmitters is recommended unless the 2% criterion is modified.

Habitat use

Habitat use was evaluated during 24-hour and 2-hour monitoring periods. Six fish were monitored for 24 hours and five fish were monitored for 2 hours. Habitat maps were either hand-drawn on data sheets or on mylar overlays of 1:2400 aerial photos.

Table 12. Summary of current radio-transmitter implants in humpback chub during 1990.

#	DATE	PITTAG	TL (mm)	WT (g)	FREQ	PULSE RATE (pulses/min)	RADIOTAG SIZE (g)	LIFE EXPEC-TANCY (days)	DATE OF EXTINCTION	CAPTURE (RM)	RELEASE (RM)
1	10/17/90	7F7F3F5050	428	840	40.670	60	11	100	910125	60.2	60.4
2	10/17/90	7F7F3E2D2D	439	865	40.640	59	11	100	910125	60.4	60.4
3	10/17/90	7F7F3F3626	432	780	40.620	78	11	75	901231	60.4	60.4
4	10/17/90	7F7F3E2253	382	535	40.650	81	11	75	901231	60.2	60.4
5	10/18/90	7F7F3F4054	415	720	40.630	39	9	50	901207	60.4	60.5
6	10/18/90	7F7F3F5044	388	580	40.680	77	11	75	910101	60.6	60.5
7	10/19/90	7F7F3F4E11	376	465	40.690	40	9	50	901208	64.6	64.9
8	10/20/90	7F7F3E2F3A	367	500	40.660	39	9	50	901209	64.6	64.7
9	10/20/90	7F7F456B2C	390	605	40.610	58	11	100	910128	64.6	64.7
10	10/20/90	7F7F3C311C	395	525	40.600	40	9	50	901210	64.6	64.7
11	11/16/90	7F7F3C4452	404	670	40.600	62	11	100	02/23/91	60.4	60.4
12	11/16/90	7F7F3C303B	396	665	40.700	62	11	100	02/23/91	60.1	60.1
13	11/17/90	7F7F3F4E77	407	675	40.710	79	11	75	01/30/91	61.0	61.0
14	11/18/90	7F7F3E3C5C	422	798	40.730	61	11	75	01/31/91	61.1	61.1
15	11/19/90	NO PITTAG	407	825	40.740	79	11	75	02/01/91	62.0	62.0
16	11/21/90	7F7F3C2919	394	635	40.640	78	11	75	02/03/91	64.1	64.1
17	11/23/90	7F7F3C4162	402	732	40.630	62	11	100	02/29/91	64.4	64.4

Table 13. Summary of radiotelemetry information collected during previous trips, 1990, and current status of radiotagged humpback chubs.

#	DATE OF LAST LOCATION[1]	FREQ	CURRENT PULSE[2]	PREVIOUS PULSE[3]	RM[4]	CONTACTED[5]	LOCATED[6]	2HR[7]	24HR[7]
1	901214	40.670	64	60	60.3	Y	Y	Y	
2	901215	40.640	54	59	60.3	Y	Y		
3	901214	40.620	68	78	60.8	Y	Y	Y	
4	901017	40.650	NC	81	(60.4)	P	N		
5	901214	40.630	39	39	60.6	Y	Y		
6	901124	40.680	-	77	(60.6)	N	N		
7	901117	40.690	-	40	(64.6)	N	N		
8	901215	40.660	39	39	64.7	Y	Y		
9	901117	40.610	NC	59	(64.6)	P	N		
10	901217	40.600	38	40	64.8	Y	Y		Y
11	901215	40.600	64	62	59.9	Y	Y		Y
12	901117	40.700	NC	62	60.9	Y	N		
13	901217	40.710	82	79	60.8	Y	Y		Y
14	901216	40.730	60	61	60.8	Y	Y		
15	901121	40.740	NC	79	(62.0)	N	N		
16	901122	40.640	-	78	(64.0)	P	N		
17	901216	40.630	65	62	64.5	Y	Y	Y	

1- Date of most recent location, from current trip or previous trips.
2- Pulse counts from current trips, NC=not counted.
3- Pulse counts from most recent contact prior to current trip.
4- River mile of last location from current trip or previous trip.
5- Indicates if fish was contacted on current trip, Y=Yes, P=Possible, N=No.
6- Indicates if specific location of fish was determined during current trip.
7- Indicates whether 2-hour or 24-hour monitoring was conducted.

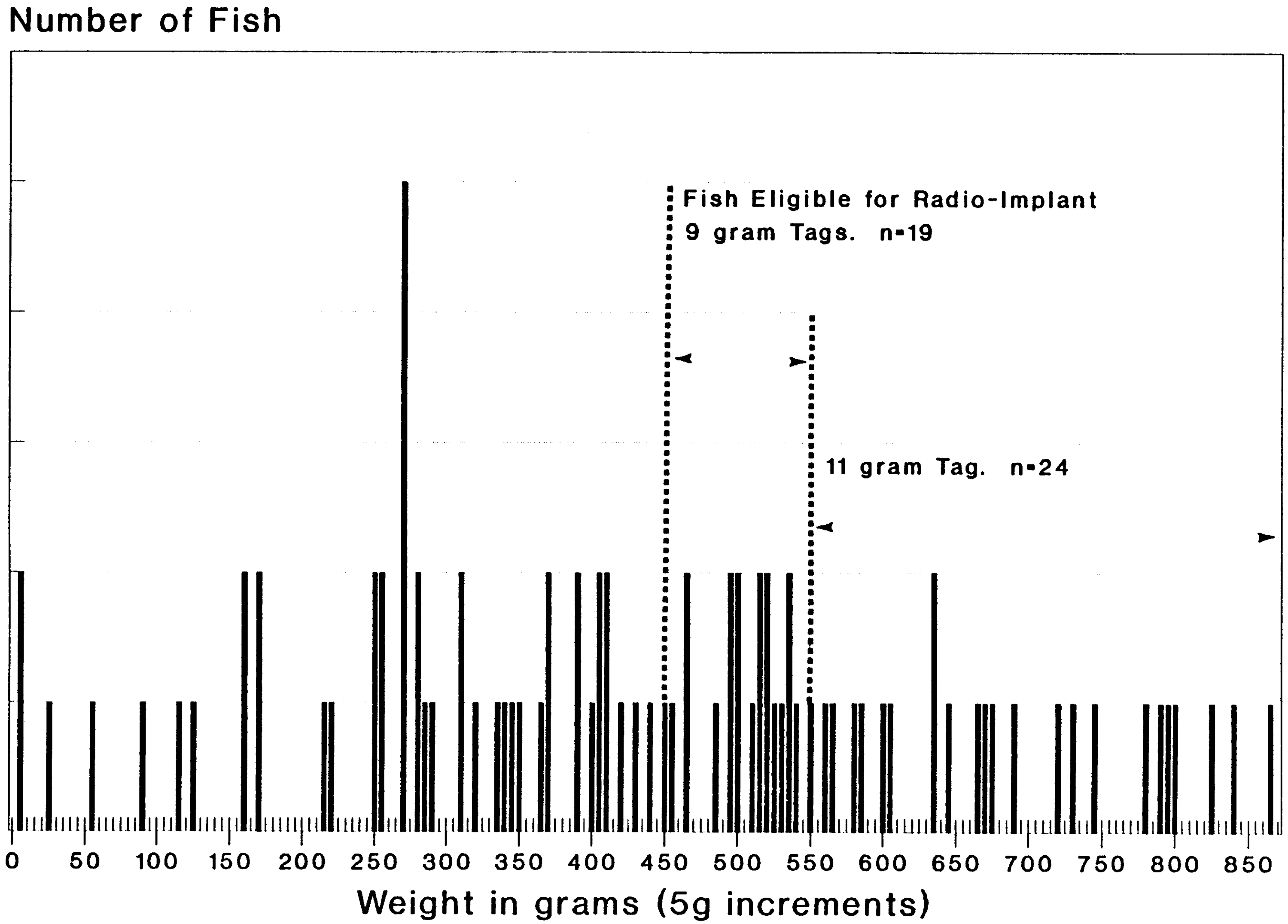

Figure 4. Weight-frequency distribution of 94 humpback chub captured in 1990, Grand Canyon Studies, 1990.

All fish monitored (2-hr and 24-hr) were using either run or eddy habitats. Specific areas used by fish were often associated with some type of instream cover, i.e. boulder fields, large solitary boulders, tapeats ledges.

Movement

Two types of movements were observed in 1990, long-range movement and local movement. Long-range movement was associated with fish that moved a significant distance. It was considered transitory because it occurred between habitats located some distance apart. Long-range movement generally occurred between trips although this type of movement was also observed during the course of a single trip (4 to 8 days). This type of movement was generally evaluated through multiple discontinuous contacts, although direct observations were made during 24-hour monitoring efforts. Long-range movement of humpback chub in Reach 1 was generally less than 0.5 miles. Fish were observed moving up to 0.3 miles and then returning to an original location, suggesting an affinity for specific locations. Limited observations suggest that flow changes may have caused these movements.

Local movement describes the activity of a fish within a localized area, with no significant change in position. This mode often involves movement within a single macrohabitat, i.e. eddy, pool, run. Local movement of humpback chub was evaluated during 2-hour and 24-hour monitoring periods. Some fish moved very little within a very specific area (100 square meters), while others were more active and moved in a larger area (0.1 square miles) occupying one or more habitats. Movement between habitats was often associated with changes in flow stage.

Vertical movement of humpback chub was also observed, as was indicated by loss of radio signal at about 4 m depth (Yard et al. 1990). It was assumed that fish were within 4 m of the water's surface when a radio signal was audible and below that level when the signal was not audible.

Constant monitoring of individual fish suggests that both horizontal and vertical movement was affected by at least three variables, (1) time of day, indicating diel fish activity, (2) turbidity level, and/or (3) river stage. Diel activity is common in many fish species, and was evident with humpback chub in the Grand Canyon. Highest activity levels, as indicated by radiotelemetry and net and electrofishing catches, were occured during crepuscular periods with lowest levels in mid-day and at night. Turbidity also appeared to affect activity. Highest activity occurred in moderate to high turbidity, and could be seen as increased local movement of radiotagged fish and net catches. It was possible to isolate the variable of turbidity by examining fish activity above and below the LCR. When the LCR was turbid, fish activity in the mainstem Colorado River was generally greater below the confluence of the LCR. The third variable that was identified as having an impact on fish movement was river stage. Fish movement generally increased with increased stage change. Statistical analyses were not performed on movement because of the small amount of data collected in 1990. Additional data will be collected in 1991 to further assess the impact of all variables that affect the behavior and ecology of the humpback chub in the Grand Canyon.

<u>Evaluation of radiotelemetry</u>

Radiotelemetry proved to be a very valuable technique for observing movement, habitat use, and behavior of humpback chubs in the LCR Reach. Radiotelemetry observations in association with capture techniques (netting and electrofishing) were particularly valuable in identifying variables that affect activity patterns and ecological requirements of humpback chubs.

Transmitter signal extinction associated with depth and high conductivities was a factor in telemetry efforts in 1990. Although depth extinction prevented monitoring fish in water deeper than 4 m, it did not preclude the collection of valuable information and in some respects, became advantageous. According to Yard et al. (1990) loss of signal occurred between 13 to 15 feet deep in the mainstem Colorado River. Due to this depth extinction phenomena, periodic loss of contact with fish was expected and did occur in 1990. The primary disadvantage associated with loss of contact was the lost opportunity to monitor fish in a randomized manner or for extended time periods at all water depths. However, depth extinction of signals has a practical application for assessing some aspects of behavior and use of the vertical water column by humpback chub. Observations during 1990 of temporal patterns of depth extinction for groups of fish suggest specific use of the water column above 4 m and below 4 m at certain times and under certain conditions. As discussed above, the variables that determine this use include time of day, turbidity and river stage.

Transmitters

Nine and 11-gm transmitters were used during 1990. The purpose for using the two sizes was to allow for a greater size range of fish to be implanted. The transmitters performed adequately for purposes of the study, although pulse rate changed more than expected (up to 10 pulses per minute). Signal frequency did not change appreciably. With a pulse separation of 20 pulses per minute for transmitters with the same frequency, drifting pulse rates could complicate identifying individual fish, although this was not a problem in 1990. Also, increased pulse rate can result in reduced transmitter life, conversely slower pulse rates can extend tranmitter life. All 9-gm transmitters (4) used in 1990 exceeded their life expectancy of 60 days.

Receivers

Both the ATS Model 2000 and Smith-Root SR-40 receivers performed adequately for purposes of the study. The advantages and disadvantages associated with the two receivers are as follows:

ATS Model 2000

Advantages:

1) High sensitivity due to tunable capability.
2) Light weight and easy to transport and use.
3) Programmable frequencies allow for versatility when searching for specific fish.

Disadvantages:

1) Monitors only one frequency at a time and the time required to scan and monitor up to 15 frequencies limits the receiver's value as a search receiver from a helicopter and during downstream travel
2) Internal batteries cannot be replaced in the field resulting in down-time during recharging.
3) Lack of a noise reduction system limits its use around motors (i.e. outboard motors, helicopters), consequently reducing its facility as a search receiver.

Smith-Root SR-40

Advantages:

1) Simultaneous scanning of 15 frequencies is desireable as a search receiver.
2) External batteries can be replaced easily resulting in no down-time.
3) Noise reduction system allows use around running motors, greatly facilitating the receivers use for searching.

Disadvantages:

1) Receiver is large and relatively heavy.
2) Lacks sensitivity of tunable receiver.

Antennae

Two antennae designs were used in 1990 including a Smith-Root bi-directional loop antenna and a Larson-Kulrod Omni-directional whip antenna. The loop antenna was used as a locator antenna in lieu of a Yagi- design since the former is more compact and easier to transport and use. Whip antennas performed well as search antennas. They attached easily with the magnetic base and are easily transported and stored. Yagi antennas are planned for use with the remote telemetry stations proposed for the LCR Reach.

Surgical Procedures

Surgical procedures for implanting radiotransmitters in humpback chub resulted in 100% recovery from surgery. All implanted chubs recovered quickly and appeared healthy, exhibiting normal behavior when released. A more complete evaluation of the surgical procedures will be possible when radiotagged fish are recaptured and incisions and fish condition are examined.

Six of the 17 radiotagged fish were not contacted one month after release. There are several possible explanations for this lack of contact, including radiotag failure, emigration from the study reach, fish occupying deep water habitats, or fish mortality.

Habitat Assessment

Habitat Use

Radiotagged adult humpback chub that were monitored in 1990 provided limited information on their habitat use in the mainstem Colorado River in Grand Canyon. Habitats utilized was primarily angular boulder piles adjacent to deep areas and steep ledges with lateral cover. The majority of humpback chub were found in either run or eddy habitats. The chubs captured in nets and with electrofishing were in similar habitats. Most chubs were collected in nets set near boulder habitats with adjacent steep ledges and deep water areas. No chubs were collected from sand or silt habitats.

Habitat Availability

Available habitats for humpback chub vary between study reaches. Reach 1 is dominated by Tapeats and Shinumo Quartzite ledges with many boulder rockfalls that provide shoreline lateral and overhead cover. The lower areas of Reach 1 below Lava/Chuar rapid (RM 65.5) are broad and shallow. The last several miles of Reach 1 contain ledge habitat with few boulder outfalls.

The Granite Gorge reach, (Reach 2), exhibits a variety of habitat. Steep schist ledges dominate the upper sections to about RM 136 where tapeats ledges dominate the middle sections with Muav limestone cliffs dominating the lower regions around Havasu Creek.

Reach 3 is characterized by a wide canyon and broad channel with little cliff or ledge habitat. Many large eddys lined with riparian vegetation dominate this reach. Tapeats ledges occur sporadically near RM 213 and small pockets of schist are found from RM 217 to Diamond Creek.

River Stage Changes

Eight temporary benchmarks were used to assess river stage changes during radiotelemetry monitoring (Table 14). Each benchmark was used in monitor stage change between hydraulic controls.

Table 14. A list of temporary benchmark locations established in 1990.

RIVER MILE	SHORE	ID NUMBER	DATE SURVEYED
60.0	LEFT	1.0600	12-17-90
60.1	RIGHT	2.0601	12-14-90
60.3	LEFT	1.0603	11-17-90
60.8	RIGHT	2.0608	11-18-90
60.9	LEFT	1.0609	12-15-90
63.9	LEFT	1.0639	11-21-90
64.5	RIGHT	2.0645	12-16-90
64.8	LEFT	1.0648	11-23-90

SUMMARY OF FINDINGS

This report reflects the results of only three field trips conducted in 1990. Data collected during these trips are too limited for analyses to address the objectives and associated hypotheses of the investigation. Therefore, the following is a summary of findings during the first four months of the project relative to each hypothesis, as well as the proposed approach and any adjustments to that approach as a result of the investigation to date.

Objective 1: To determine the ecological and limiting factors of all life stages of humpback chub in the mainstem Colorado River, Grand Canyon, and the effects of the Glen Canyon Dam operations on the humpback chub.

A literature review is being conducted to determine the known ecological requirements of the humpback chub. A comprehensive library of information on the humpback chub is currently being assimilated by C.O. Minckley as part of a separate project. BIO/WEST has contributed to this library and will use it as the basis for determining known ecological requirements of the species. The BIO/WEST literature review will focus on known habitat use, water quality conditions, and biological needs of the species in the lower and upper Colorado River basins. A list of known ecological requirements or criteria will be developed to compare with existing conditions of the Colorado River in the Grand Canyon. This background information will provide a perspective on the life history requirements of the species in order to determine if specific ecological factors are lacking or limiting in the Grand Canyon, and how these factors are impacted by Glen Canyon Dam operations. This literature review and list of criteria will be assimilated early in 1991.

Field investigations are currently focused on filling data gaps and informational needs on the critical life history requirements of the humpback chub in the mainstem Colorado River. Intensive sampling is being conducted in the mainstem to determine seasonal distribution, abundance, movement patterns, resource use and availability, and survivorship of the various life stages. Changes in habitat parameters are being monitored during scheduled research flows to determine if the operation of Glen Canyon Dam limits or enhances these basic ecological needs of the species. Each of the following sub-objectives or tasks will be addressed by testing one or more hypotheses (Ho):

Task 1A: **Determine resource availability and resource use (habitat, water quality, food, etc.) of humpback chub in the mainstem Colorado River.**

Ho 1A-1: **Habitat is limiting under certain flow conditions to humpback chub in the mainstem Colorado River, Grand Canyon.**

Too few measurements of micro and macrohabitat were taken in this investigation in 1990 to characterize habitat use and availability. Observations of radiotagged adult humpback chub showed that most fish remained in very specific locations (microhabitats) for extended periods of time from October through December. Movement from these locations and from macrohabitats was seen at different times of the day and night, with different flow levels and changes, and under different turbidity levels. These variables together with geomorphic channel type have been identified as being the primary variables that affect habitat selection. A sampling program is being designed around radiotelemetry monitoring to measure these variables in order to understand the relationships that affect the fish.

This hypothesis will be tested by identifying the habitat parameters most used by humpback chub and observing the changes to and availability of these parameters at different flow levels and stage changes (ramping rates). This task identifies habitat availability and use in order to determine if habitat is limiting.

Macrohabitat availability will be determined for each of the three study reaches with the aid of selected aerial photographs available from Reclamation, and through still and video photography from permanent riverside stations. Aerial photographs were not available in time to begin this mapping process in 1990, but are being made available for start of this task early in 1991. The area of each macrohabitat type (backwaters, eddies, pools, runs, riffles, rapids, slackwaters, etc.) will be mapped on mylar overlays at different water levels using existing aerial photographs and direct observations similar to the technique employed by Valdez and Masslich (1990) in the Green River, Utah. Changes in surface area of macrohabitats will be interpreted between mylar overlays with the aid of an AutoCad Computer System. This analysis will establish relationships between area of specific macrohabitat types and flow levels and provide a quantification of macrohabitats in each of the three regions by river flow.

Micro and macrohabitat used by adults are being determined from radiotagged fish during an established radiotelemetry monitoring program. Radiotelemetry has been used to describe habitat and local movement of humpback chub in the Upper Basin (Valdez and Nilson 1982, Valdez and Clemmer 1982, Kaeding et al. 1990) and was the preferred tool for developing habitat suitability index curves for the species (Valdez et al. 1990). Microhabitat is described in terms of depth, velocity, substrate, overhead cover, and lateral structure in association with radiotagged fish. Associated macrohabitat will be mapped on aerial photographs and changes documented during monitoring. Changes in river stage are being monitored with temporary bench marks.

Habitat of YOY and juveniles is being determined from capture information with the use of seines, minnow traps, and experimental gill nets in shallow shoreline habitat and backwaters. This sampling is being done concurrently with the AGF backwater program which has been ongoing for several years.

Ho 1A-2: Water quality is limiting under certain flow conditions to humpback chub in the mainstem Colorado River, Grand Canyon.

Regularly scheduled water quality sampling has not been implemented in this investigation. Existing USGS water quality gages will be used to monitor ongoing water quality parameters of the

Colorado River. Hydrolabs are being used to describe water quality parameters associated with specific areas (e.g. tributary inflows) and events (e.g. floods).

Sudden and dramatic movements of fish will be closely monitored to determined if these are caused by changes in water quality or other factors. Concentrations of fish particularly around tributaries or springs will be documented and water quality parameters measured to identify relationships. Also, a thorough literature review will be conducted to identify limiting ranges of water quality parameters for humpback chub. This information will be related to existing conditions of the Colorado River in the Grand Canyon and to the present status of the species in the study area.

Turbidity is considered an important variable that may affect the behavior and distribution of humpback chub in the Grand Canyon. Since the species evolved in a highly turbid river system and has been shown to be negatively phototrophic (Bulkley et al. 1982), removal of silts and sands through settlement in Lake Powell may be affecting its life history and behavior. Behavior relative to turbidity will be monitored for radiotagged fish using their occurrence in the uppermost 4 m of water as an index of near-surface use. Since radiosignal extinction occurs at about 4 m (Yard et al. 1990), the occurrence of radiotagged fish near the surface can be separated from use of deep water during different levels of water clarity. Telemetry surveillances will be conducted during the four light periods (dawn, day, dusk, night) to determine if near-surface habitat use is related to light penetration and therefore water quality. Also, stomach contents of the fish will be examined to determine if feeding periodicity is affected by turbidity (See hypothesis Ho 1A-3).

Turbidity in the study area is affected by tributary inflow, local rainfall, debris flows, and the operation of Glen Canyon Dam. This parameter will be measured on a diel basis during each sample trip. An index of light penetration will also be taken with a Sechi disk during radiotelemetry monitoring and surveillance. A relationship will be established between readings from a limnophotometer and a Sechi disk.

Ho 1A-3: Food is limiting under certain flow conditions to humpback chub in the mainstem Colorado River, Grand Canyon.

A food habits study of humpback chub in the Grand Canyon will be initiated in 1991. A feasibility study has been developed to evaluate use of nonlethal stomach pumping methods by using surrogate species such as roundtail chub and bonytail chub. Stomach content analysis is critical in characterizing the life history and ecology of the humpback chub in the Grand Canyon. Food habits, combined with food availability information from drift and benthic samples, will be assessed to determine if dam operations are affecting the availability of food resources as well as the timing of availability. Stomach contents of humpback chub will be sampled during various flow scenarios to determine if changes in behavior (i.e. additional movement) are induced by greater food availability or changes in habitat.

Leibfried (1988) found that rainbow trout below Glen Canyon Dam ingest large quantities of *Cladophora*, deriving nutritional benefit through digestion of lipid-rich diatoms epiphytic on the algae. It is important to know if humpback chub exhibit similar feeding strategies since *Cladophora* production is closely linked to stream flow and hence dam operation. This relates to flow as well as temperature regimes. Certain flow scenarios may affect production of *Cladophora* and temperature changes are likely to affect epiphytic diatom communities (Blinn et al. 1989).

Food habits of humpback chub will be examined by a nonlethal method using the principle of a stomach pump. Fish will be mildly anesthetized with MS-222 before inserting the inlet tube into the esophagus. The stomach will be mildly irrigated with water to flush material into a collecting funnel and container. Material pumped from each fish will be stored separately and examined in the laboratory to determine composition and volume.

Task 1B: Determine the reproductive capacity and success of humpback chub in the mainstem Colorado River.

Ho 1B-1: Humpback chub do not actively spawn in the mainstem Colorado River, Grand Canyon.

Main channel reproduction by humpback chub in the Grand Canyon is at best extremely limited, or more likely nonexistent as a result of cold water temperatures (Maddux et al. 1987). Attempts will be made to determine if spawning occurs in the mainstem in 1991 by observing the nuptial condition of captured fish and by following closely the movements of radiotagged fish suspected of being in spawning condition. Sudden movements and aggregations of radiotagged fish may lead to specific spawning locations that can be confirmed by intensively sampling the area with various gears for gravid females and ripe males. Discovery of such an area will invoke intensive sampling for eggs and larvae.

It is also possible that radiotagged fish will ascend to spawn in one of several tributaries in the Grand Canyon (Little Colorado River, Shinumo Creek, Havasu Creek, Kanab Creek, Bright Angel Creek, Tapeats Creek). A concerted effort will be made to radiotag at least 15 adults during the March 1991 trip in order to provide sufficient numbers of radiotagged fish for tracking during the spawning period of late April and May. A concerted effort will be made during these two months to track these fish. Also, two remote telemetry stations will be established on the mainstem at the mouth of the LCR, one to monitor fish moving from upstream and one to monitor fish moving from downstream. Radiotagged fish that ascend these tributaries will be followed and data collections will be coordinated with the Service and AGF. The lower reach (1-2 km) of these tributaries will also be routinely ground searched for radiotagged fish when crews are in the vicinity. Tributary inflow areas will also be sampled intensively during suspected spawning periods to determine if spawning is occurring in tributary deltas warmed by the inflow.

Spawning locations, concentration areas, and staging areas identified in the mainstem will be mapped in detail at various flow stages. Cross sectional profiles will be taken with stadia rods and sonar units, substrate will be assessed, and velocities will be measured where possible. Shoreline habitats near and below suspected spawning areas will be sampled intensively to confirm the presence of YOY chubs and to assess their relative densities as well as habitat use.

Task 1C: **Determine the survivorship of early stages of the humpback chub in the mainstem Colorado River.**

Ho 1C-1: **Survival of early life stages of humpback chub is low in the mainstem Colorado River, Grand Canyon.**

Relatively few young humpback chub were captured in 1990. This may reflect the gear types and efforts expended or low densities of the young fish in the mainstem. Efforts will be made in 1991 to employ more gear types (i.e. minnow traps, seines, small-mesh hoop nets, electrofishing and experimental gill nets) to capture the young fish.

Survival of early life stages of humpback chub will initially be assessed primarily on age-0 fish entering the mainstem from the LCR. Intensive sampling will be conducted at the mouth of the LCR in late May and early June to capture large numbers of age-0 humpback chub for mark and release. These fish will be marked by clipping a small portion of the caudal fin. A mark of longer duration is urgently needed in order to follow the survival of these fish over several years, but none has been developed to date. Ideally, the age-0 fish from the LCR should be permanently marked within the system by investigators from ASU and AGF so that these marked fish can be followed into the mainstem and the proportion of escapement and residence determined for the LCR as well as survival rates in the two systems.

Survival of age-1 and age-2 fish will also be difficult to assess without the aid of a permanent mark. These fish are still too small to PIT tag and fin clips retain their identity for only short time periods. Fish that are age-3 and older should be large enough to PIT tag (>175 mm TL) and assessing survival of age-3 and age-4 fish is possible. However, distinguishing age-5 fish and older is difficult because of variable and inconsistent growth rates for individual fish. Information currently being assimilated by other investigators (AGF, ASU, D. Hendrickson, C.O. Minckley) on age-length and age-growth relationships for humpback chub will aid in differentiating age groups of particularly the younger fish. Length-frequency analyses will be made for fish captured in this investigation and others in the Grand Canyon to relate survival of known length fish to age group survival. It is anticipated that age-0 through age-4 fish will be distinguishable from length-frequency analysis, but older fish may not be distinguishable because of the affect of maturation and spawning on growth. Thus, survival rates of humpback chub will be determined separately for age-0, age-1, age-2, age-3, and age-4 fish while survival of all adults is treated as a group.

If spawning is found in the mainstem, attempts will be made to gather information on spawner numbers, fecundity, and escapement as input into population modeling efforts.

Task 1D: **Determine the distribution, abundance and movement of the humpback chub in the mainstem Colorado River, and effects of dam operations on the movement and distribution of humpback chub.**

Ho 1D-1: **The distribution and abundance of humpback chub in the mainstem Colorado River, Grand Canyon, is affected by Glen Canyon Dam operations.**

The above hypothesis will be tested by assessing the potential effects of dam operation on the distribution and abundance of the species. First, the distinction must be made between the effect of the presence of the dam and its operation. Most investigators (Carothers et al. 1981, Maddux et al. 1987) believe that cold water releases, irrespective of fluctuating flows, have reduced the pre-dam distribution and abundance of the species.

The pre-dam and current post-dam distribution and abundance of humpback chub in the mainstem Colorado River, Grand Canyon, are not accurately known. Pre-dam data from the mainstem are nonexistent except for some sampling at the LCR and its influence area (Kolb and Kolb 1914, Miller 1946, Wallis 1951). Post-dam information is primarily from the LCR Reach but scant from the other sample reaches. This study will attempt to refine known seasonal distribution and abundance information on humpback chub in the mainstem Colorado River, Grand Canyon, by using sample methods previously described in this document. These sample efforts are expected to confirm recent collection locations of the species and possibly identify additional locations.

The affect of the present operation of the dam on the distribution and abundance of the species will focus on habitat dynamics and tributary access. Habitat availability will be determined as described under hypothesis Ho 1A-1. This analysis will determine the distribution and availability of habitat at various flows. Also, access by fish into six key tributary streams (LCR, Bright Angel, Tapeats, Shinumo, Kanab, Havasu) will be evaluated by measuring water depth and velocity at the mouth for fish passage at various flow stages. Passable depth and velocity measurements will be related to mainstem flows in order to identify water conditions that could allow access by adults into these tributaries for spawning. Acceptance of this hypothesis is based on the assumption that increased access into these tributaries would enhance reproduction by humpback chub and thus distribution and abundance.

Ho 1D-2: **Cold water releases from Glen Canyon Dam affect the distribution and abundance of humpback chub in the mainstem Colorado River, Grand Canyon, independent of dam operations.**

The influence of cold water releases (40° F) on the distribution and abundance of humpback chub in the Colorado River, Grand Canyon, independent of fluctuating flows, will be evaluated in order to determine if the presence of Glen Canyon Dam alone determines distribution and abundance or if these factors are determined by fluctuating flows as a result of dam operations.

This hypothesis will be tested by examining the temperature requirements of each life stage of the species, and comparing with existing temperature regimes in the Grand Canyon. Consideration will also be given to balancing detrimental affects of cold temperature on the species with the beneficial affect of excluding predators and competitors.

Another aspect of temperature that will be examined is as it affects epiphytic diatom communities. Leibfried (1988) determined that rainbow trout in the Grand Canyon utilize diatoms epiphytic on *Cladophora* as a primary source of lipids. Blinn et al. (1989) observed significant changes in these epiphytic diatom communities when water temperature was increased from 12°C to 18°C, but no change was observed between 18°C and 21°C, suggesting a temperature threshold between 12°C and 18°C for diatom flora below Glen Canyon Dam. Increased water temperature could significantly affect food resources of the fish species in the Grand Canyon that exhibit the same feeding strategy as humpback chub.

Ho 1D-3: Movement of humpback chub in the mainstem Colorado River, Grand Canyon, is greater during fluctuating flows than during stable flows.

The affect of fluctuating flows will be assessed on two modes of movement by humpback chub, long-term and short-term movement. Long-term movement is defined as total movement by a fish over an extended period of time, observed between seasons or years. It is often related to spawning but may be related to temperature preference, or food or habitat availability. Long-term movement is determined primarily from recaptured PIT-tagged or fin-clipped fish.

Short-term movement is observed movement by a radiotagged fish during 2-hour or 24-hour monitoring. These movements are often part of diel movement patterns, or are in response to feeding behavior, habitat changes, or sudden and dramatic changes in water quality (e.g. large sediment load from debris flow). Long-term movement may occur during short-term observations as in spawning movements.

Short-term movement in response to fluctuating or stable flows will be assessed by observing individual radiotagged adults for periods of 2 to 24 hours. Movement of each fish will be determined in distance and time between locations occupied for 30 minutes or more. Each location will be pinpointed by triangulation from the nearest shore and indicated on a 1:2400 scale map for accurate measurements of movement.

A concerted effort will be made to sample near designated tributaries and coordinate efforts with the ongoing AGF and Service programs in these tributaries since the greatest impact of fluctuating flows may be in staging areas at tributary mouths. Telemetry surveillance will be conducted in the lower 3 km of the LCR during each of our tracking trips to determine if radiotagged humpback chub are occupying the lower reach of this tributary. Tracking will be conducted by helicopter and by at least two people on foot following each of the banks of the stream with radio-receivers. Specific movements and habitat use of individual radiotagged fish will be monitored during scheduled flow releases in order to ascertain the reaction of the fish and their habitat to flow changes. Fish movement will be mapped on mylar overlays using aerial photographs of the study areas to indicate changes in habitat during the GCES research flows. Our findings to date indicate that the research flows are not amenable to fisheries investigations. Since it is necessary for us to establish 'control' conditions for movement and habitat use of adult humpback chub, stable flows are needed at 5,000; 10,000; 15,000; and 20,000 cfs. These flows would have to be of a 5-day duration in order to allow the fish to adjust to conditions. Our observations during short-term (72-hour recalibration) flows in 1990 suggest a lag period of readjustment.

Task 1E: Determine important biotic interactions with other species for all life stages of humpback chub.

Ho 1E-1: Introduced non-native fish species have a negative effect on humpback chub in the mainstem Colorado River, Grand Canyon.

Various aspects of the life history of the humpback chub may be affected by certain biotic interactions with other species of fish such as channel catfish, carp, rainbow trout, brown trout, and striped bass. The possible influence of competition and predation by these exotic species will be identified and separated from the effects of dam operations. Stomachs will be examined from sacrificed channel catfish, striped bass, and brown trout year-around to determine the degree of predation on the various life stages of humpback chub. Where possible, predators will be captured with hook and line to avoid possible biases imposed by conventional sample gears (regurgitation, consuming other species while holding in hoop nets). Carp will also be sacrificed and examined during and shortly after spawning to determine if this species preys on eggs and young.

Other interspecific interactions such as overlap in habitat use and food resources will be evaluated by keeping records of all fish captured during sampling. These interactions will be described by reach, habitat type, tributary influence, and size of fish.

Objective 2: Determine the life history schedule for the Grand Canyon humpback chub population.

The life history of the humpback chub in the Grand Canyon will be described with the aid of existing literature and data gathered from this field investigation, designed to fill the data gaps and informational needs. Population characteristics will be described including, but not limited to, distribution, abundance, density, growth, and survivorship. Individual statistics will be also be assimilated including, but not limited to, fecundity, growth, survival, and movement. Also, spawning time and conditions, appearance of larvae, habitat use by age group, and movement of fish between the mainstem and tributaries will be described as well as length-weight, length-frequency, catch-per-effort, sex ratios, and age structure statistics. Information on the life history of the humpback chub in the Colorado River, Grand Canyon, will be integrated with information collected on the species in tributaries to gain a better understanding of this endangered species in this region.

Task 2A. Develop or modify an existing population model from empirical data collected during the study for use in analyses of reproductive success, recruitment and survivorship.

Information and data assimilated from literature as well as collected from year-around sampling will be used to describe the life history of the humpback chub in the Grand Canyon. The empirical data collected on the various life history aspects of the species will be integrated with other investigations into an existing population model being developed under the guidance of GCES. This model will be used as a tool to identify relationships and functions of components.

B/W currently has a statistician/population modeler on this project to advise data collection and analyses, as well as input to demographic modeling. All collections are being made, to the extent possible, to provide as much information as possible to this modeling effort.

RECOMMENDATIONS

1. Continue fish sampling with same gear types including electrofishing, gill nets, trammel nets, hoop nets, and seines. Expand effort at sampling habitats used by younger fish with small-mesh hoop nets and minnow traps. Also increase sample effort with electrofishing.
2. Implement geomorphic strata as sample strata for sample design in Reach 2. Implement concept for data analysis for entire study area.
3. Modify contract in 1991 to sample confluence of Paria River.
4. Further evaluate aerial telemetry.
5. Explore possibility of remote telemetry to assess other aspects of humpback chub behavior such as vertical movement (above 4 m depth)
6. Activate a volunteer program to satisfy manpower needs during both 20-day trips (to clean nets) and 10-day trips (to help sample fish and radiotrack).
7. Track and monitor radiotagged fish in the LCR and provide locational information to AGF, ASU, the Service.
8. April and May 1991 trips will be scheduled to optimize assessing spawning of humpback chub.
9. Lengthen April 1991, trip by 2 days to maximize opportunity to observe spawning, and decrease fall or winter trip.

10. Coordinate modeling efforts early with other investigators to meet data collection needs for demographic model.

11. Coordinate habitat analysis with Larry Stevens on depth and velocity contours.

12. Define mapping issues (i.e. use of GIS, MIPPS, etc.).

13. Develop standardized base maps for the Colorado River, Grand Canyon with river miles on 1:2400 scale.

14. Consider stable research flows of 5-day duration at 5,000; 10,000; 15,000; and 20,000 cfs. Possibly extend post research flow in July 1991 or present 72-hour recalibration flows.

15. Survey temporary bench marks to permanent bench marks as soon as possible before temporary bench marks become indistinguishable.

16. Increase number of radiotagged fish implanted in March to 15 in anticipation of spawning in April and May, but implant only females.

17. Make data available from ongoing studies in a reasonable time for use by all investigators.

18. Reduce meristic measurements to 1 of every 10 fish, but continue to photograph and video all fish.

19. Use existing USGS stations to collect ongoing water quality. Use Hydrolabs to collect point location information such as at tributary inflows, springs, and during spates.

20. Develop Sechi disk to limnophotometer relationship; use Sechi disk on all observations.

21. Establish remote monitoring station to measure turbidity.

22. Modify sampling reaches to reflect geomorphic strata and realistic sampling areas. Reach 1 would extend from RM 56 to RM 77.4 (was 76.5), Reach 2 would extend from RM 77.5 to RM 159.9 (was 156), and Reach 3 would extend from RM 160.0 to RM 226.

23. Discontinue use of radiotransmitters with frequency of 40.690 to avoid interference from errant signals caused by Hydrolab in USGS station at the LCR.

24. Reduce use of 9 gram transmitters and use more 11 gram transmitters to extend observation time of individual fish.

23. Modify Annual Reporting dates:

From:	DRAFT	FINAL
	January 15, 1992	January 31, 1992
	January 15, 1993	January 31, 1993
	January 15, 1994	January 31, 1994
To:	DRAFT	FINAL
	February 28, 1992	March 31, 1992
	February 28, 1993	March 31, 1993
	February 28, 1994	March 31, 1994

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